



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

**ECONOMICS OF FISHERY FAILURE: THE FALL OF THE  
KING-ANALYSIS OF UNITED STATES WEST COAST  
CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA)**

by

Michael J. Hoshlyk

September 2011

Thesis Advisor:

William R. Gates

Second Reader:

Robert E. Looney

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KING-ANALYSIS OF UNITED STATES WEST COAST  
CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA)**

Michael J. Hoshlyk  
Commander, NOAA Commissioned Corps, Pacific Grove, California  
B.S., University of Rochester, 1988

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**NAVAL POSTGRADUATE SCHOOL  
September 2011**

Author: Michael J. Hoshlyk

Approved by: William R. Gates  
Thesis Advisor

Robert E. Looney  
Second Reader

William R. Gates  
Dean, Graduate School of Business and Public Policy

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## **ABSTRACT**

This study examines bio-economic trends within the West Coast wild salmon fishery, specifically the Chinook (King) salmon *Oncorhynchus Tshawytscha* species. This study will first review the historical management, policies, competing interests, and environment affecting the health of the wild Chinook that brought the fishery sector to its current status. It focuses on fisheries supply data derived from both farmed aquaculture and troll caught (wild) salmon off the West Coast of the United States (California, Oregon, Washington, and Alaska) from 1980–2007. The study will then describe the wild Chinook fishery market and assess the effect of the farmed fishery supply and the long-term implications of changes in consumer preferences in conjunction with a growing farmed fish market and declining regional fishery availability. The data of the declining West Coast stocks, growth of wild imports and global salmon aquaculture data reflect the supply changes that have occurred in the salmon market both prior to and during this period. The study further examines the long and short-term economic implications of the development of international commercially farmed salmon fisheries upon the wild salmon fishery.

Analysis of historical trends assesses the effects of status quo policy and management in the salmon fishery and resulting historical and current supply and demand curves as a means of forecasting future market pricing. The study will show how United States wild salmon stocks are vital to U.S. supply and competition in domestic and international salmon markets and how variability in that stock at low levels will most likely continue absent significant government policy revisions and will directly impact premium market pricing.

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## **LIST OF ACRONYMS AND ABBREVIATIONS**

AABM	Aggregate Abundance Based Management
ASMI	Alaska Seafood Marketing Institute
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
ISBM	Individual Stock Based Management
LOS	Law of the Sea
MBP	Maximum Biological Production
MEY	Maximum Economic Yield
MSC	Marine Stewardship Council
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	Maximum Sustainable Yield
NGO	Non-Government Organization
NMFS	National Marine Fisheries Service
PacFIN	Pacific Fisheries Information Network
PFMC	Pacific Fishery Management Council
PST	Pacific Salmon Treaty

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To my father for his pride, support, and encouragement.

*I dedicate this thesis in memory of my mother.*

– Michael J. Hoshlyk

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## I. INTRODUCTION

For well over a century, western North American salmonid (*Onchorhyncus* spp.) species have sustained both regional and worldwide demand by the aggregate of total poundage harvested and in value to commercial and sport fisheries. From the onset of United States Pacific states fisheries market, the wild Chinook salmon has been regarded as the keystone salmon fishery supply, accounting for as much as 8% of salmon caught in California and Oregon (Yoshiyama, 1998). In 2008, for the first time in the history of the West Coast Chinook fishery, the decline of this fishery reached a sufficiently low abundance level to prevent enough harvest to support domestic and export market demand. This supply, by most projections, will remain level or continue to decline (Netboy, 1980; Nehlsen et al., 1991; Cone & Ridlington, 1996; National Research Council, 1996; Lackey, 1999a; Lichatowich, 1999; Knudsen et al., 2000).

The reason for the decline in West Coast Chinook stock, to the point of fishery closure, may be explained by reviewing fishery management policy and its long-term economic effect. Over a 170-year period, competing stakeholders placed pressures on the wild stock fishery management in the form of water regulation, dams, water diversions for irrigation, over-fishing, hatcheries, and land development that resulted in a cumulative adverse effect on all salmon life stages (Montgomery, 2003), and the resultant decline in the fishery. Ironically, for the past forty years, technology and management aimed at improving salmon production, while being reactive to wild stock declines, have generally either failed to improve salmon harvest or, in some cases, led to further decline of wild stock (Lufkin, 1996).

### A. LIFE HISTORY

The Chinook salmon, *Oncorhynchus tshawytscha*, (pronounced cha-vee-cha) is also known as King, Tyee, Spring, Quinnot, Blackmouth<sup>1</sup> (immature) salmon. The Genus *Oncorhynchus* comes from the Greek, meaning “hooked nose,” and dates at least from the

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<sup>1</sup> Color inside mouth distinguishes immature Chinook from other salmonids.

Pliocene era (Smith, 1975). *Tshawytscha* is a phonetic approximation of the name used by native Koryak peoples of the Kamchatka Peninsula; derived by Georg Wilhelm Steller's account and later observed and confirmed by Johann Julius Walbaum (Steller, 1741). Early scientific and commercial records from Washington and Oregon often reported chum salmon as "kings" or "yellow kings." As Chinook salmon also are called "kings," this name confusion makes historical estimates of abundance difficult to ascertain for both species.

Morphologically, the Chinook is the largest of the seven species of anadromous and semelparous salmon (Healey, 1991). Of the North American Salmonidae family (Pink, Coho, Chinook, Chum, Sockeye, Steelhead, Cutthroat), five of the species (Chinook, Chum, Coho, Pink, Sockeye) are commercially caught in western North America. Of these, only the Chinook and Coho have been found to have the growth, yield, quality, and survivability for farmed aquaculture. As the largest species, Chinook make for the iconic wild landing in both commercial and sport fisheries. Chinook or Kings command the highest market value compared to other stocks of salmon and other regional fish available for harvest.

Chinook growth is rapid during ocean life, often exceeding one pound (0.45 kilograms) per month. Chinook generally mature over a period of one to nine years, with average time to maturity being three to five years. Adults then innately return to natal streams to spawn. Adult Chinook salmon range from 33 to 36 inches and can grow up to 58 inches in length; weighing from 10 to 50 pounds, and up to a record 126 pounds (Scott & Crossman, 1985).

Chinook migrate from the sea in four distinct runs identified by their timing: spring, summer, fall and winter. Runs developed according to regional seasonal climate depending on natal stream consistency and the distance needed to travel for stream-type species (Gilbert, 1913). The majority of Chinook spawn in the middle and upper main stems of rivers and in larger freshwater stream tributaries and watersheds. Each run timing is widely distributed and is characterized by a different suite of life history survival patterns, including juvenile smolt age, oceanic distribution, adult run timing, spawning location, age at maturity, and fecundity (Healey, 1983, 1991) (Figure 1), which

spreads the risk of mortality across both years and habitats (Stearns, 1976; Real, 1980). Juvenile salmon exhibit two general life history strategies: stream and ocean type. Stream-type juveniles may stay for up to two to three years in less productive or more northern streams, where growth is slower, before heading seaward (Healey, 1983, 1991).

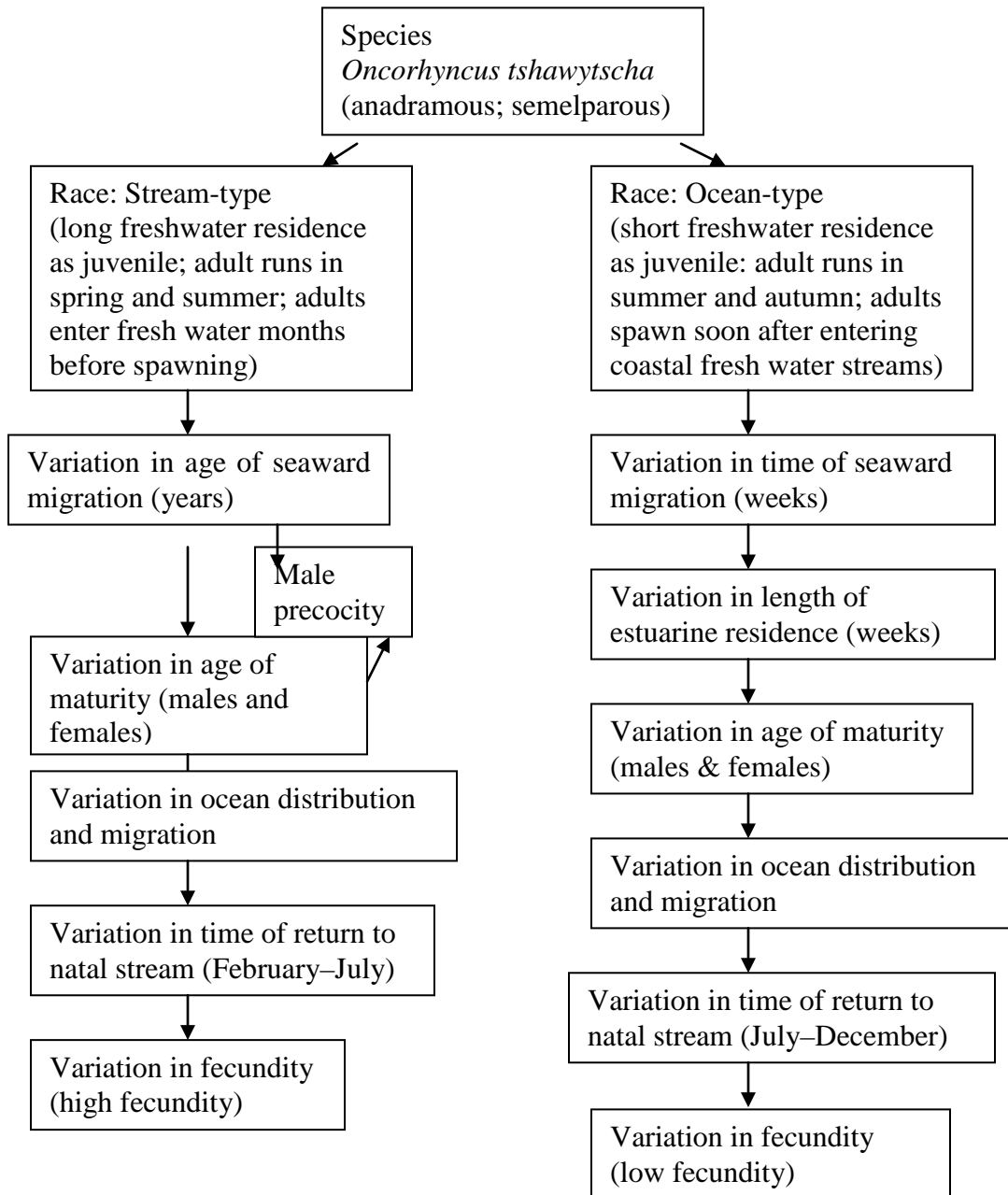


Figure 1. Life history structure of Chinook salmon showing the division of the species into two races (ocean and stream-type) and the range of tactical variation within each race (From: Healey, 1991).

Upon leaving the rivers of Oregon, Washington, and British Columbia, juvenile Chinook move up the coast in a northwesterly direction to feeding areas off southeast Alaska or British Columbia (Figure 2).

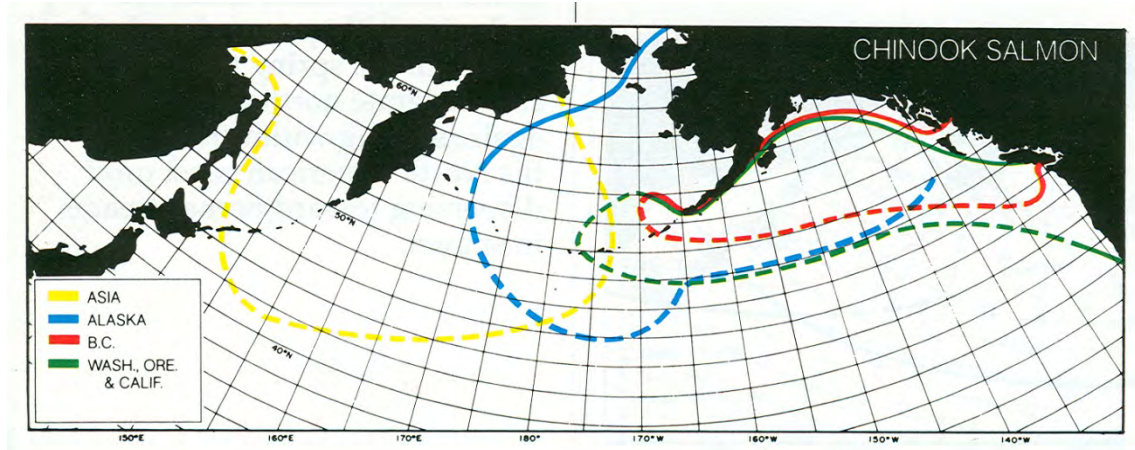


Figure 2. Pacific range of Chinook Salmon (From: Fisheries and Oceans Canada, 2008a).

## B. HISTORY AND BACKGROUND OF CHINOOK SALMON FISHERIES

Chinook salmon have survived for two million years and may differ genetically in different rivers as a result of adaptation to a specific watershed or adjustment to a changing one. Human population growth and related environmental changes continue to take a toll on wild salmon fisheries. In North America alone, the geographic distribution and abundance of more than one thousand Chinook salmon spawning populations originally ranged from southern California to Point Hope, Alaska (Figure 3). The major U.S. fishing areas for Pacific salmon have historically been Washington-Oregon-California, British Columbia, Southeast Alaska, Central Alaska, and Western Alaska. Chinook are also found along the coast of Siberia and south to Hokkaido Island, Japan. In the Pacific Northwest, habitat loss for 90% (175 of 195) of native naturally spawning salmon and steelhead stocks parallels the growth of human population, hydropower development, and habitat destruction in the West Coast salmon watersheds (NMFS, 2008a) (Figure 4).

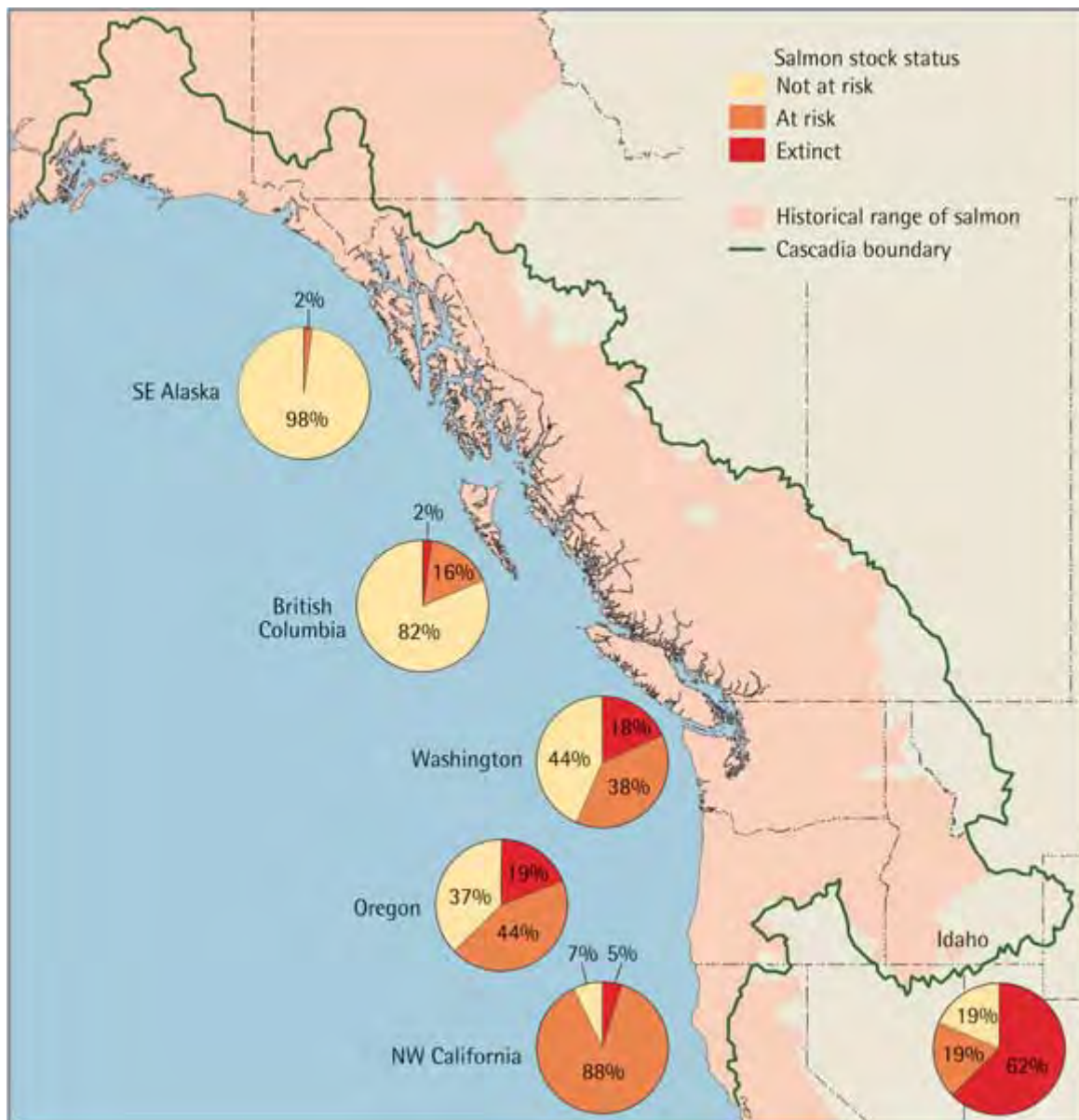


Figure 3. Salmon current and historic range with regional stock status (From: Cascadia Scorecard, 2006).

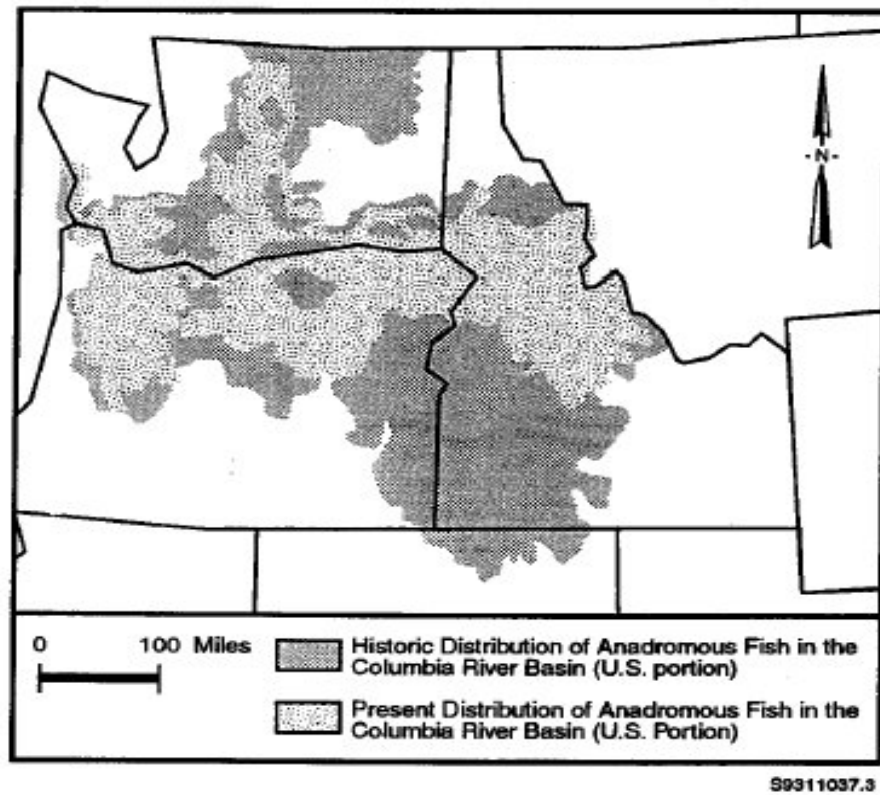


Figure 4. Historic v. present distribution of anadromous fish in the Columbia River System River Basin (From: NPPC, 1992).

## **II. WEST COAST DEVELOPMENT**

Pressure on North America's West Coast Chinook may be traced back prior to the development of stock management in the United States, to the discovery of gold in California in 1848. Western expansion, as a result of the gold rush, led to subsequent and continued population growth in California, Oregon, and Washington. By 1850, a commercial fishery had developed in California. Additionally, the purchase of Alaska from Russia opened the door to expanded settlement in the far north. In the late 1870s, the first salmon canneries were established in southeastern Alaska, pre-dating the first Alaskan gold discovery in 1880.

### **A. CANNERIES**

On the West Coast, the largest rivers supported the largest-ever recorded aggregate runs and largest spawning salmon populations. Canneries started on the Sacramento River in 1858. Chinook spawned in the main flow and nearly every tributary of the Columbia River (NOAA, 1998), and the first canneries on the Columbia River were formed in 1866. Figure 4 shows the extent of the Columbia River system, historic and present salmon distribution. After the commercial Chinook production reached an all-time high in 1883, the survey of "The Salmon Fishing and Canning Interests of the Pacific Coast" (Jordan & Gilbert, 1887) was completed. Oscillations in supply were noticed, however, as early as 1889; when stock catch declined by 58%, as shown in Figure 9 (Yoshiyama, 1998). As discussed later in this report, Figure 9 shows the long-term decline in the Columbia River Chinook catch that occurred over a 100-year period.

In Alaska, as gold strikes continued into the 1890s, development, as on the West Coast, included operations to increase both gold and salmon yield. The Alaskan salmon fisheries, however, also began to show depletion within just twenty years of establishing the first cannery in Alaska (Cooley, 1963). The extensive western decline resulted in the first Pacific states legislation, directing fisheries management to protect the runs of

salmon during migration up the rivers and on spawning grounds (Yoshiyama, 1998). In 1889, the U.S. Congress adopted the Alaska Salmon Fisheries Act, which prohibited erecting dams or other obstructions on salmon streams (Cooley, 1963).

## B. DAMS

Installation of dams on the major West Coast rivers in California, Oregon, and Washington continued and directly resulted in declined river stocks, which in turn led to a coastal fishing harvest increase (Yoshiyama, 1998). The extent of the central California river system that at one time supported Chinook stocks is shown in Figure 5. In parallel, Figure 6 shows the timeline of dam construction activity in California, which correlates directly with declining salmon populations over the period.



Figure 5. Major historical salmon producing streams of Central California drainage. Only lower mainstems are shown. (From: Yoshiyama, 1998).

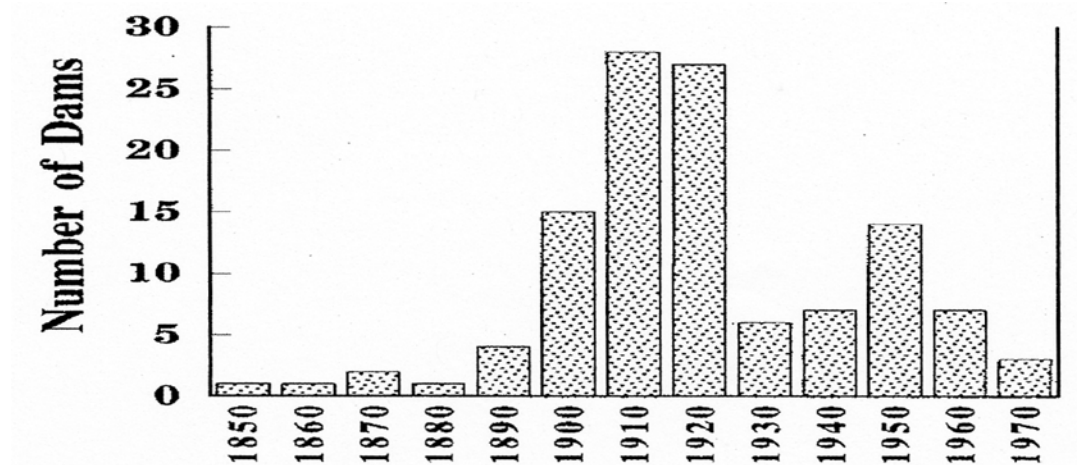


Figure 6. Timeline of California dam construction (From: Yoshiyama, 1998).

Stock decline from 1920s projects continued into the 1930s and 1940s; in particular, California's water-use projects adversely affected river stocks, already at 25% of their historical catch (Figure 7). Dams frequently blocked the migration of salmon to natal streams and in this construction period, mitigating this barrier was not addressed. Runs were also destroyed by destructive logging and mining practices, resulting in scouring or silting of the spawning areas.

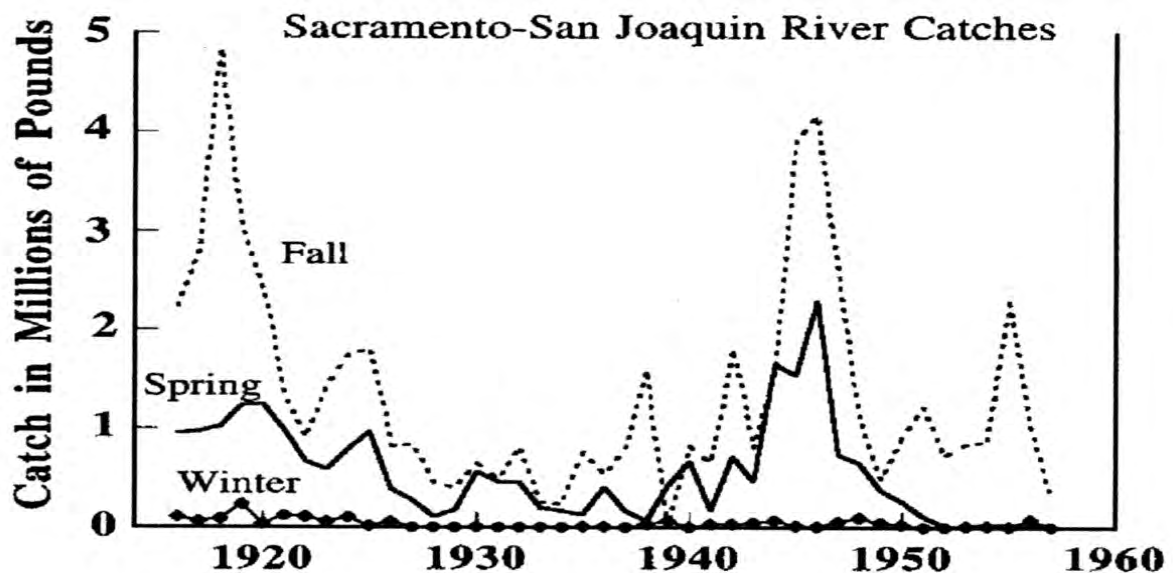


Figure 7. Chinook salmon catch 1910–1960 (From: Yoshiyama, 1998).

### **C. FISHERIES DECLINE**

In the early expansion years of the West Coast Chinook fishery, the Sacramento-San Joaquin River system was the backbone of California salmon fishing. Unregulated salmon landings from 1856 to 1947, shown in Figure 8, resulted in fishers supplying all the catch they could deliver to market. In 1880, the total unregulated commercial catch was eleven million pounds; by 1922, the catch dropped to seven million pounds; by 1939, the catch was less than three million pounds.

The decline in the California catch from the late 1920s to early 1940s was attributed to overfishing, dams, diversion of water for irrigation and power, and stream pollution. Fisheries management observed the need to limit impacts on watersheds to preempt the same result from happening in many more streams (Fry, 1949). Beginning in 1942 and into the 1950s, the San Joaquin River was diverted to California's Central Valley agriculture, thereby further reducing the river flow to seasonal, if not dry, in the summer. This diversion quickly resulted in the extinction of most runs of the San Joaquin Chinook. Figure 8 shows the decline of the Sacramento/San Joaquin stock during this period; a pattern similar to the decline in the Columbia River fishery. The Sacramento/San Joaquin fishery was closed in 1957.

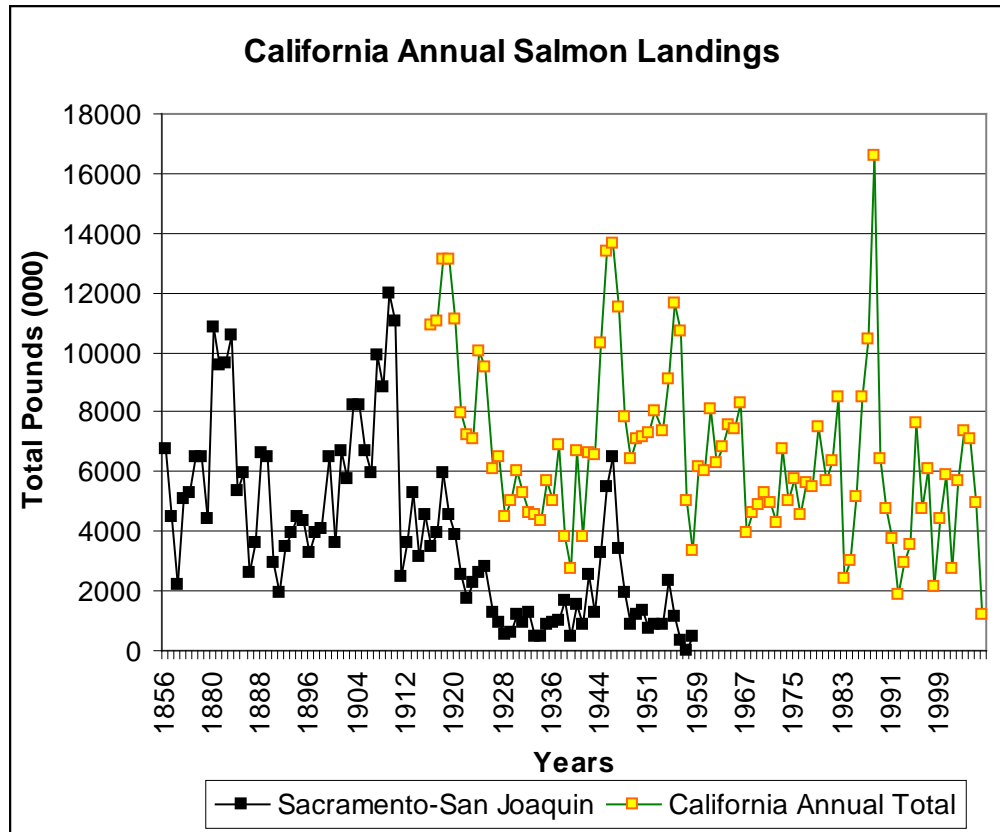


Figure 8. California Chinook salmon annual landings 1856–2007 (From: NMFS, 2008b).

On the Columbia River, harvest of Chinook and Sockeye began in 1886. After an initial sharp decline first observed around 1890, harvest of Columbia River Chinook salmon remained fairly constant until about 1920; overall it declined thereafter. In 1925, just prior to completing the Columbia River dam, a drop in salmon harvest occurred (Figure 9). Just prior to 1940, most Columbia River stocks were harvested in the river, where river harvest numbers are a good indication of run trends during this period (Fulton, 1968). By 2007, the Columbia River Basin saw less than 2% of its historic fall run return.

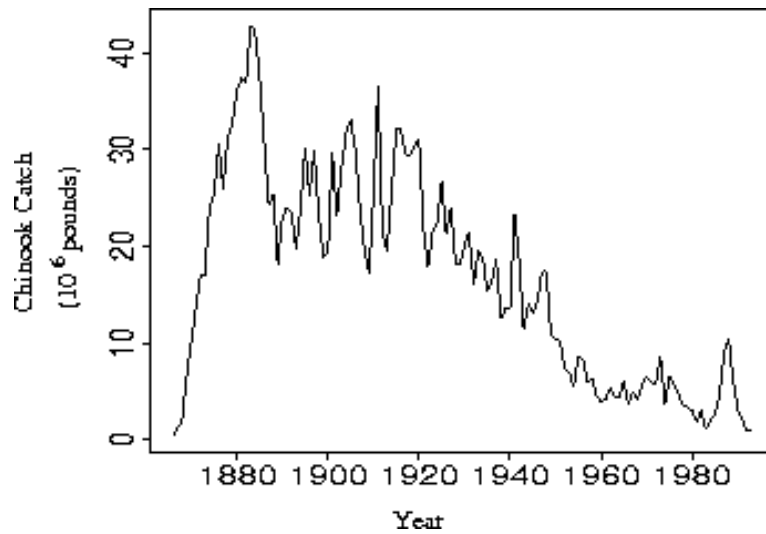


Figure 9. Total Chinook catch on the Columbia River 1870–1990 (From: Yoshiyama, 1998).

The resulting salmon declines on major West Coast rivers led to several evolutionary significant units (ESUs) now listed as endangered or threatened according to U.S. Endangered Species Act (ESA) stipulations, as shown in Figure 10 (Heard et al., 1995; NMFS 1993; Waples, 1991a).<sup>2</sup>

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<sup>2</sup> National Marine Fisheries Service stipulates that in determining 1) whether a population is distinct for purposes of the ESA, and 2) whether an ESA species is threatened or endangered, attention should focus on “natural fish,” which are identified as the progeny of naturally spawning fish.

<b>Oncorhynchus Tshawytscha Chinook Population</b>	<b>Listing Authority</b>	<b>Listing Status</b>	<b>Listing Date</b>
Sacramento River Winter-run ESU	National	Endangered	Jan. 1994
Sacramento River Winter-run ESU	California	Endangered	Sep. 1989
Snake River Fall-run ESU	National	Threatened	Apr. 1992
Snake River Fall-run ESU	Oregon	Threatened	Dec. 2000
Snake River Spring/Summer-run ESU	National	Threatened	Apr. 1992
Snake River Spring/Summer-run ESU	Oregon	Threatened	Dec. 2000
Puget Sound ESU	National	Threatened	Mar. 1999
Lower Columbia River ESU	National	Threatened	Mar. 1999
Upper Willamette River ESU	National	Threatened	Mar. 1999
Upper Columbia River Spring-run ESU	National	Endangered	Mar. 1999
Central Valley Spring-run ESU	National	Threatened	Sept. 1999
Central Valley Spring-run ESU	California	Threatened	Feb. 1999

Figure 10. Endangered/threatened West Coast Chinook populations. (From: NMFS, 2008a).

In less than a century's time, the cumulative losses resulting from demand for hydropower and water, land development and population growth caused serious degradation in the salmon fisheries habitat in of the major river systems (Columbia, Klamath, Sacramento) in Washington, Oregon and California, respectively. In Oregon,

the Klamath River fall Chinook is the primary management stock that determines ocean commercial catch. The fall Sacramento Chinook is usually the strongest stock with three of every four fish caught off of Oregon originating from the Sacramento River. Both of these catches have been affected by multi-year seasonal (2006–2008 closures).

#### **D. HATCHERIES**

With decline in wild stocks, West Coast wild salmon stock management sought to augment production from hatcheries in rivers, where domestication of certain declining runs is possible (PFMC, 1996). Hatchery technology offered the potential for artificial propagation. In California's Central valley, all salmon runs had suffered permanent habitat losses to varying degrees (Fisher, 1994). Use of hatchery-raised stock was intended to offset losses due to dam and other river system obstructions. Hatchery programs operating in other areas of the Pacific Northwest were developed primarily as mitigation measures for degradation of salmon production due to habitat loss or overfishing (Heard, 2003). The assumption was that substantial habitat and carrying capacity must still exist in the ocean despite stock decline due to overharvest, dams and habitat destruction (Heard, 2003).

In response to the growth of farmed fish, the suitability for farming the Chinook species was examined. Following a period of depressed commercial salmon fisheries in Alaska, a major effort to expand aquaculture research and production began in the 1970s. The program was intended to supplement, not supplant, wild stock production (McGee, 2004). Salmon farming was later prohibited by the Alaska legislature in 1990.

Success from hatchery augmentation has proven limited, as many of the associated watersheds also require curtailing the processes responsible for degrading the wild stock. Hatchery returns mask the problems of native stock loss and create false impressions about the overall salmon fisheries health and the environment (Lufkin, 1996). Hatchery fish also stray, and, if from non-native stocks, this increases the potential for interbreeding, genetic homogenization, and mixed-stock fisheries. This further reduces regionally unique adaptive genetic distinctions and life-history strategies (NMFS-NWFSC-35, 1995).

Ricker (1980), studying British Columbia salmon, observed that the increased pressure of hatchery salmon at 90% harvest rates combined with wild salmon, which could stand a maximum harvest rate of 65%, further depleted wild stock populations. In British Columbia, about 30% of the spawning salmon population has been lost since 1950 (Riddell, 1993). The repeated failure of hatchery stock to improve wild stock production demonstrates that inserting additional stock to increase aggregate production does not restore the supply. Hatchery practices are also based on a constant environment, which is a major error due to environmental oscillations and variability in the expanse of salmon habitat.

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### III. MANAGEMENT

#### A. EVOLUTION OF THE UNITED STATES AND INTERNATIONAL SALMON MANAGEMENT

The current state of fisheries stock management has evolved over centuries. Management is historically influenced by the waters within which the fish stock is found. Over the last 800 years, nations have moved from limiting to expanding territorial jurisdiction based upon economic resources and strategic implications. Sovereignty and exclusive economic fisheries ownership were effectively banned by the Magna Carta in 1215 and again in the 17th century by Grotius in *Mare Liberum* claiming ‘free seas.’ In the late-19th century, coinciding with the rise of new technology and growth of fishing fleets, there was realization that over-fishing was a distinct possibility as accessible river and coastal stocks began to decline. At that time, the three-mile limit, derived in the early 18th century, set a nation’s territorial maritime boundary as the distance within which it could be protected by cannon shot.

Over time, as stocks continued to decline, sovereignty was extended further offshore to establish the right to protect living and non-living resources and sustain commercial gain. United States concern over foreign fishing and interception of North American origin stocks on the high seas and in the North Pacific Ocean and Bering Sea began in the early 20th century. As regional river stocks continued to decline, the fishery began to develop coastally and offshore. The presence of long-range Japanese driftnet vessel fishing was one of the aggravations between the United States and Japan during the 1930s, prior to World War II (U.S. Dept. of State Press Releases, pp. 412–417).<sup>3</sup>

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<sup>3</sup> The U.S. government made a statement in this regard to the Japanese government, stating, *inter alia*, that: “The American Government must view with distinct concern the depletion of the salmon resources of Alaska. These resources have been developed and preserved primarily by steps taken by the American Government in cooperation with private interests to promote propagation and permanency of supply. But for these efforts, carried on over a period of years, and but for consistent adherence to a policy of conservation, the Alaska salmon fisheries unquestionably would not have reached anything like their present state of development.”

In 1945, President Truman issued a proclamation claiming U.S. jurisdiction over U.S. continental shelf resources to maintain food production from the sea on a sustained annual basis by maintaining and establishing conservation zones in parts of the high seas (Selak, 1950). This asserted that a foreign nation ought to abstain from entering a fishery if the stock of fish concerned is already fished and is regulated and conserved by another nation or nations (Selak, 1950). This resulted in an “abstention line” established at 175 degrees west longitude, with Japan agreeing to abstain from fishing east of this line. Subsequent post-World War II negotiations between the United States, Canada, and Japan resulted in the International North Pacific Fisheries Convention (INPFC) and established a tripartite commission to research and manage high seas harvested salmon.

From the 1950s through the 1980s, gear technologies improved and the North Pacific fishing nations of Japan, Korea and Taiwan developed long range, high seas driftnet fishing fleets at a rate outpacing effective regulation (Balwebber, 1990). In 1966, the U.S. Congress expanded claimed jurisdiction beyond the 3-mile state limit to 12 miles. U.S. commercial fishery landings, however, continued to decrease while foreign catches grew to more than double that of the U.S. catch. Offshore areas in the mid-1970s supported 15%–20% of the world’s traditionally harvested fish resources (NAPA, 2002).

In 1976, Congress enacted the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) to establish a U.S. fisheries control zone from three to 200 miles offshore; ultimately declared an exclusive economic zone (EEZ) in 1983. The MSFCMA, based upon equity and economic rational, asserted U.S. sovereignty over “all anadromous species that spawn in U.S. waters, throughout their migratory range, except when they are in another nation’s territorial sea”. For a few years after MSFCMA, the majority of the catch continued to be harvested by foreign fishing fleets. The American Fisheries Promotion Act of 1980 further articulated the goal of decreasing foreign rights over the EEZ and orchestrated a decrease in foreign catch allocations; domestic fishing and processing capacity expanded (NAPA, 2002). As a result of these legislative actions, it is likely that the high seas harvest of some western Alaskan stocks of salmon were reduced by as much as 80% (Pennoyer, 1979).

In 1985, the Pacific Salmon Treaty (PST) between the United States and Canada was designed to ensure that each country received benefits equivalent to its own production and stock management conservation rebuilding or enhancement programs. This treaty set overall catch limits and percentages of intercepted hatchery and stream fisheries for stocks originating from Alaska, British Columbia, Washington, and Oregon.

Under the subsequent 1999 PST Agreement, regional fisheries councils are subject to Individual Stock Based Management (ISBM) or Aggregate Abundance Based Management (AABM) provisions, as well as constraints to meet the U.S. Endangered Species act for threatened and endangered Chinook salmon stocks. ISBM management goals mandate conservation of more important stocks, like the Chinook. The 1999 Chinook Annex to the PST also adopted the Alaskan style abundance-based management that calculates allowable catch using annual abundance, estimated pre-season and in-season, and escapement, rather than long-term averages, fixed quotas or historical catch maxima. The 2008 treaty negotiated by the Pacific Salmon Commission, for the period 2009 to 2018, called for Canada and Alaska each to reduce its catch by 30% and 15%, respectively, with the goal of increasing Chinook returns by 3%–7% in the upper Columbia River.

## **B. STOCK MANAGEMENT POPULATION MODELS**

Since the mid-19th century, a long term, staged decline in western state Chinook has occurred. A slide and ratchet model by Lawson (1993) and Anderson, J.J. (1997), as shown in Figures 11 and 12, depicts a population extinction slide driven by increasing cumulative anthropogenic impacts on the salmon population at various life stages,  $\alpha(t)$ , and a constant climatic effect  $\beta$ . The salmon decline, a population ratchet to extinction, is driven by increasing cumulative anthropogenic impacts,  $\alpha(t)$ , and a climatic cycle  $\beta(t)$ . This model bears distinct resemblance and is relevant to long term West Coast stock decline, proposed by Lawson (1993, Figure 11) and Lichatowich and Mobrand (1995), when production of Columbia River and Sacramento/San Joaquin based Chinook salmon are graphically compared (J. L. Anderson, 1997).

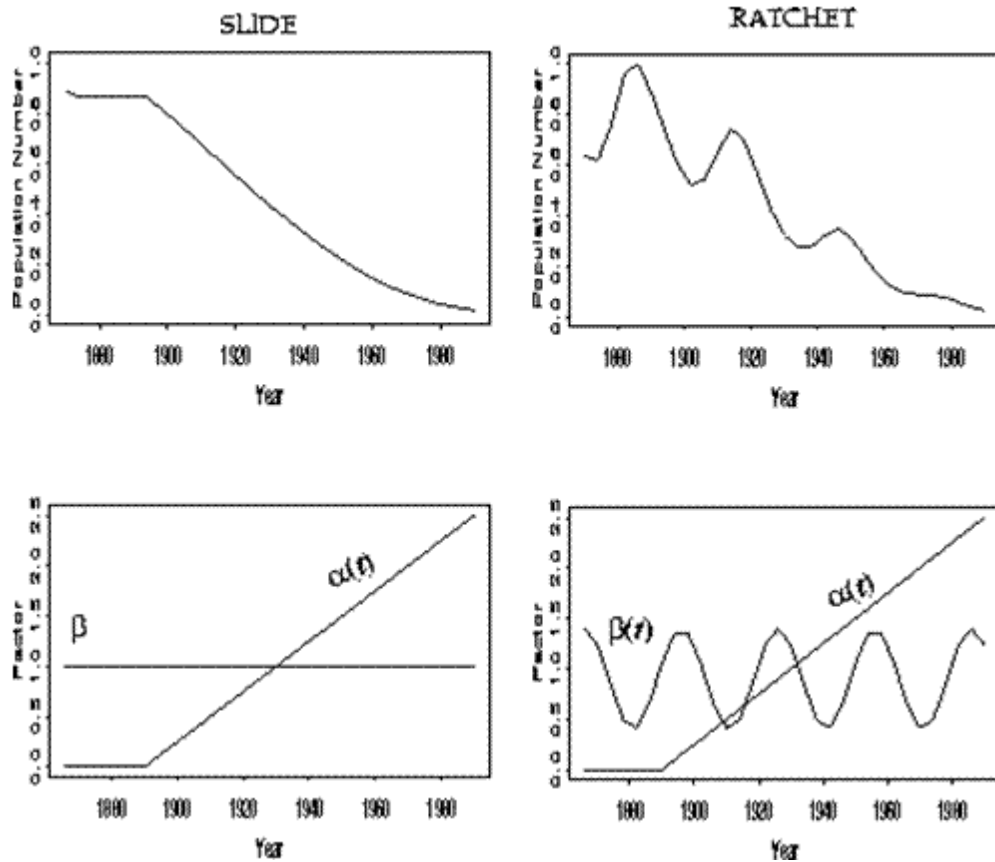


Figure 11. Slide and ratchet population slides (From: J. L. Anderson, 1997).

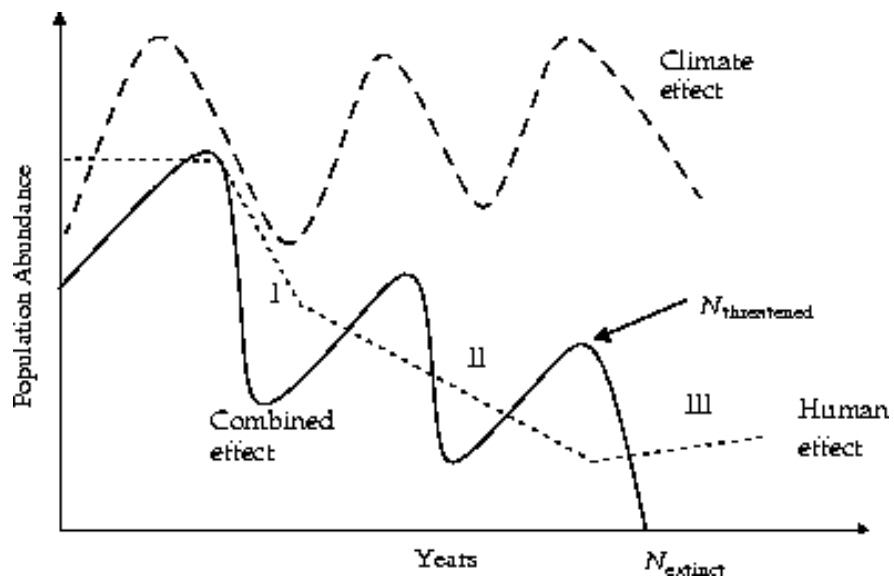


Figure 12. Combined effect in population abundance due to climatic and human effects (From: J. L. Anderson, 1997).

Prior to human exploitation pressure, wild salmon populations experienced variation with natural climatic cycles (Lackey, 2003). For the salmonid, the adaptive life history strategy over millions of years developed species survival traits partially in response to climatic cycles. When combined with rapid and intensive human resource exploitation pressure, which includes habitat degradation, the direct effects and results are amplified and population abundance precipitously declines.

The combined population effect, Figure 12, is shown to occur over three stages. Within each of the stages, the stock experiences a biological reduction, which in turn leads to an economic yield reduction. Stage I is an expansion in which the population is directly or indirectly affected without regard to the consequences. In this stage, awareness of the resource grows. For West Coast salmon, this initially occurred in the mid to late 19th century. In the early 20th century, as West Coast salmon fisheries moved downstream and coastal, there was additional expansion and stock pressure.

In Stage II, activity is controlled through regulation oriented to achieve a return, such as to maximize yield or to distribute the economic benefits of the resource. This stage represents a period of stability, with some variations in abundance. Variations in production lead resource managers to propose regulations to optimize the yield. For West Coast salmon, this represents the attempts of 20th century stock management.

Stage III follows if Stage II fails to sustain the population. In Stage III, the population's existence is threatened and mitigation actions are necessary to recover the population, *as shown* in Figure 12. This is the current West Coast Chinook population stage at the start of the 21st century.

In Figure 13, the x-axis value represents the additional effort required to maintain harvest levels over time as the stock declines, resulting in less catch per unit of effort. The initiation stage (A), concurrent with Stage I, generally begins with low fisherman density levels and depends much on the state of social development in which the fishery is pursued. As an example, West Coast salmon were plentiful in all the major river systems during the initiation stage (1840–1890). As fishing effort increased after 1890, the fishery harvest rate declined in catch per unit effort. The beginning of the sustained

exploitation phase (B) that follows reflects stock levels that are relatively stable. The late 19th century through the dam propagation period (1890–1950), even while comparatively stable, shows an increase in effort and a decline in catch per unit of effort. As effort increases, the variability in environmental conditions and in the stocks (C) changes the composition and abundance of the harvested fish stock, which further declines and destabilizes. At (D), effort pressure begins to fluctuate and destabilize the resource. As this effort continues to increase, there is a progressive and dramatic reduction in catch. Collapse occurs when the fishery stock is reduced below that which ensures a sustainable exploitable population ( $N_{threatened}$ ).

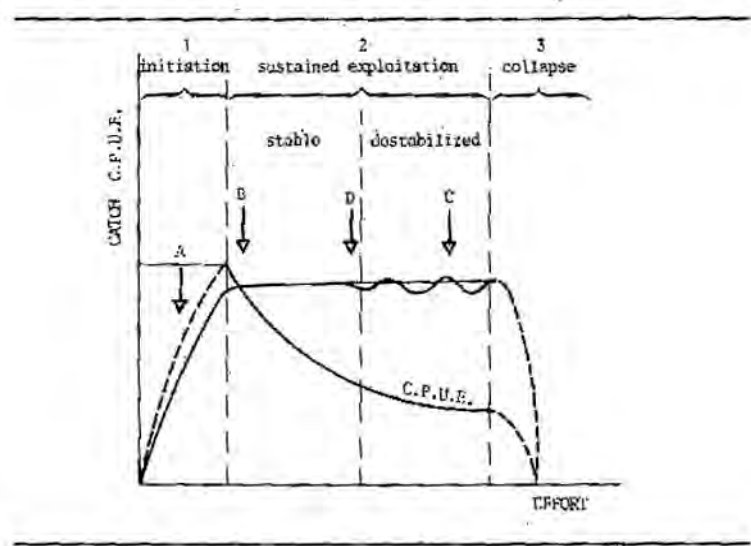


Figure 13. Stages of fishery in terms of Catch Per Unit Effort (C.P.U.E) and Effort (From: J. L. Anderson, 1997)

At present, the stock collapse is evidenced by closure of the Chinook salmon fisheries in all of the major West Coast river systems (Columbia, Klamath, and Sacramento). In the Sacramento River and related drainages in California, 1 million to 3 million Chinook salmon spawned annually. In 2008, the third stage of the model is apparent as only 50,000 salmon are expected to return to the Central Valley (Sacramento) river systems and streams originating in the western Sierra Nevada. Studies indicate that about 80% to 90% of the historic riparian habitat has been lost in western salmon run

states. Further, during the last 200 years, approximately 53% of all wetlands in the lower 48 United States have been lost. Washington and Oregon's wetlands have been diminished by one third, while it is estimated that California has lost 91% loss of its wetland habitat (NMFS, 2008a). Unfavorable ocean conditions in 2005 and 2006 also played a significant part in further ratcheting down Chinook in the early part of their four to five year life cycle (ADF&G, 2008).

### **C. MAXIMUM SUSTAINABLE YIELD**

The collapse of a fishery after sustained exploitation suggests that management models failed to adequately comprehend the extent of the declining production yield. Traditional fisheries management has focused on Maximum Sustainable Yield (MSY)—defined as the highest running catches that can be taken year after year without reducing stocks below sustainable replenishment capacity. In the 1960s and 1970s, MSY was seen as the ideal target in managing fisheries. The 1982 United Nations Convention on the Law of the Sea (LOS) endorsed MSY as an established measure for managing fisheries (Cady & Mahon, 1995). Using this management model, however, most commercial fish stock yields have declined to well below peak sustainable production capacity.

The obvious problem with MSY is the social trap in fisheries, where the short-run micro-motives of an individual fisher are not consistent and compatible with the long-run macro-results that all fishers desire (Schelling, 1978). An individual fisher's incentive has typically been to harvest as much as possible, as quickly as possible, and compete, for the greatest possible share (Gordon, 1954; Scott, 1955); this leads to over-harvesting on the macro-level. The challenge management faces is how to address and balance the unsustainable stakeholder micro-motives within the constraints of narrow and diverse political legislation, while using a faulty set of assumptions promoting a sustainable fishery harvest.

The foundation of salmon management is based on the optimistic goal of maximizing the yield from an aggregation of stocks (Bevan, 1988), not from concerns about risk and loss. Figure 14 depicts MSY for a stock size ( $X$ ) and annual growth  $F(X)$ . If the MSY of a stock was known, the stock when harvested at that level ( $X_{MSY}$ ) would,

in theory, be stable, matching the annual growth rate of stock restoration, all other factors constant. Harvest levels in region A are below both MSY and maximum annual growth, and MSY remains viable without degrading the potential. The annual growth rate would remain at a yield supporting the potential for harvest at MSY. Contrarily, in region B, when harvest exceeds MSY and the population density is reduced, annual stock growth potential is degraded and is insufficient to maintain or restore MSY. With successive harvest levels in region B, stocks decline.

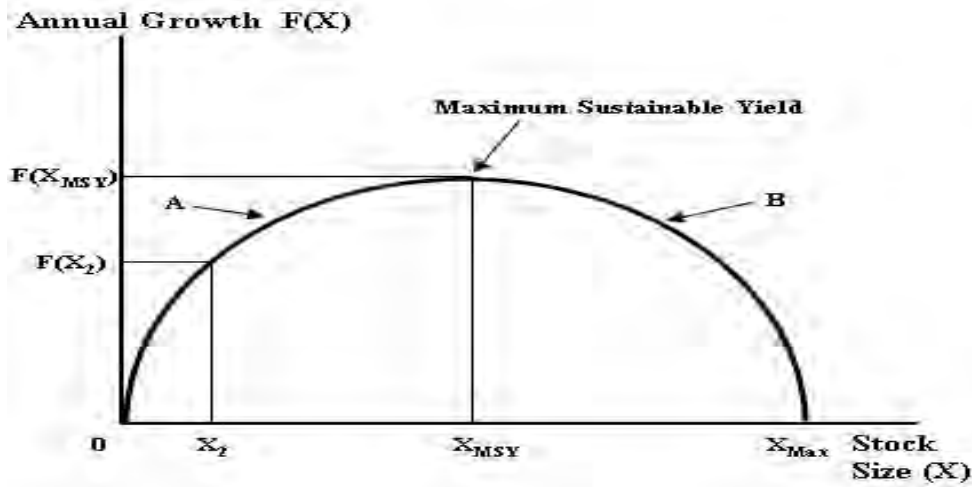


Figure 14. MSY relative to stock size and annual growth (From: Schaeffer, 1954).

While harvest at MSY theoretically yields the biggest sustainable catch, the risk borne is the decrease in future yield, when the catch exceeds biological production (Figures 14 and 15). This basis, however, has been found to be in error as it is impossible to precisely estimate the MSY for any stock ex ante (Cady & Mahon, 1995). Less than precise biological production estimates over decades resulted in managers having incomplete information on stock variation. If MSY is consistently over-estimated, which has been the historical tendency, the take due to effort increase will reduce biomass production year after year, driving the stock toward an unsustainable level if effort is not reduced. Harvest at or in excess of MSY and stock stability occurs without adjusting conservation measures. In other words, multi-year harvests often exceeded MSY and

progressive fish stock or biomass decline follows because all other nonconstant factors were omitted, not weighted, or not considered. The MSY concept is, therefore, more of an upper limit reference point for sustainable management without resulting in stock decrease.

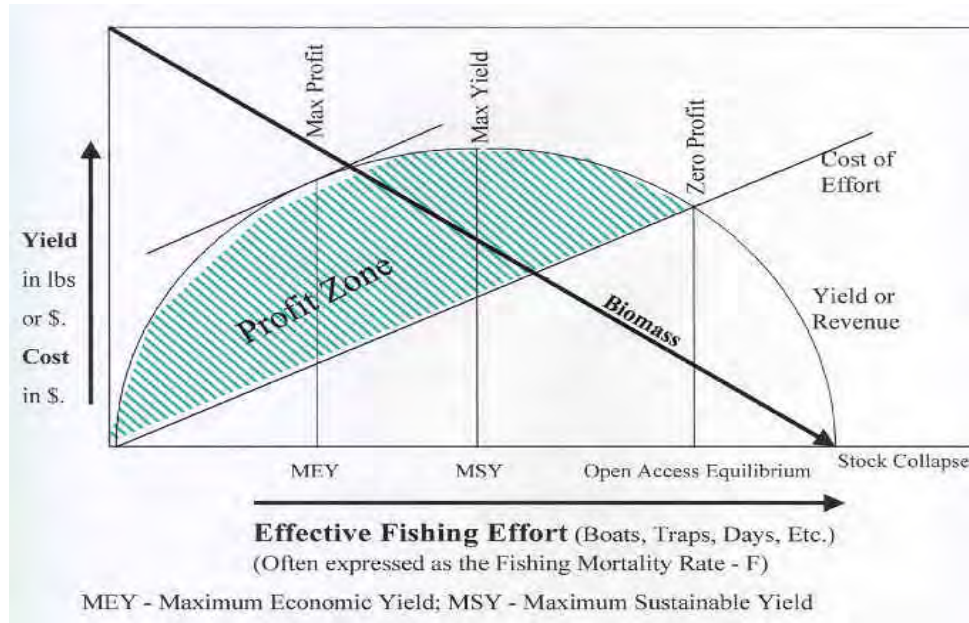


Figure 15. Profit yield with respect to effort source (From: Schaeffer, 1954).

Fishers would be economically ahead over a sustained period if catch does not exceed MSY; fishers, however, have a historic tendency to increase catch until marginal profits are driven to zero. If stocks are managed at maximum economic yield (MEY), depicted in Figure 15, a buffer theoretically pads stock variation due to adverse environmental conditions and inaccurate management yield predictions.

#### D. MAXIMUM ECONOMIC YIELD

The overlay of Stock Size and Annual Growth (Figure 13) with Yield and Effective Effort (Figure 15) shows the stock size and harvest effort required relative to yield and annual growth in a fishery. In parallel view, the key observation is the decline in biomass and yield or revenue with effort exceeding stock size and annual yield or growth. Stock biomass is the overall total fish population comprising the stock, which declines over time if effort and harvest exceed maximum yield. In Figure 15, a fishery's

MEY occurs where revenue exceeds cost by its largest margin; profit is at a maximum and the stock biomass is sustainable. For a range above MEY, profits are still positive as revenues exceed costs, but profits are lower than at MEY because the cost of effort increases faster than revenue. At MSY, revenue is maximized. Beyond MSY, cost of effective fishing effort increases as revenue decreases because there is a decrease in harvestable biomass. At MSY, profit decreases below its maximum. Management's goal, however, has been to arrive at MSY. When MSY is exceeded, and revenue continues to decrease while cost of effort increases, a point is reached where the unsustainable yield eliminates economic profit.

Figure 16 displays difference between maximum value and maximum yield for a complex multi-species, multi-run, multi-cohort fishery, like salmon. The sustainable yield curve maximum yield requires more effort than seeking maximum gross value. The maximum gross value reflects a yield associated with the biological production curve of Figure 17.

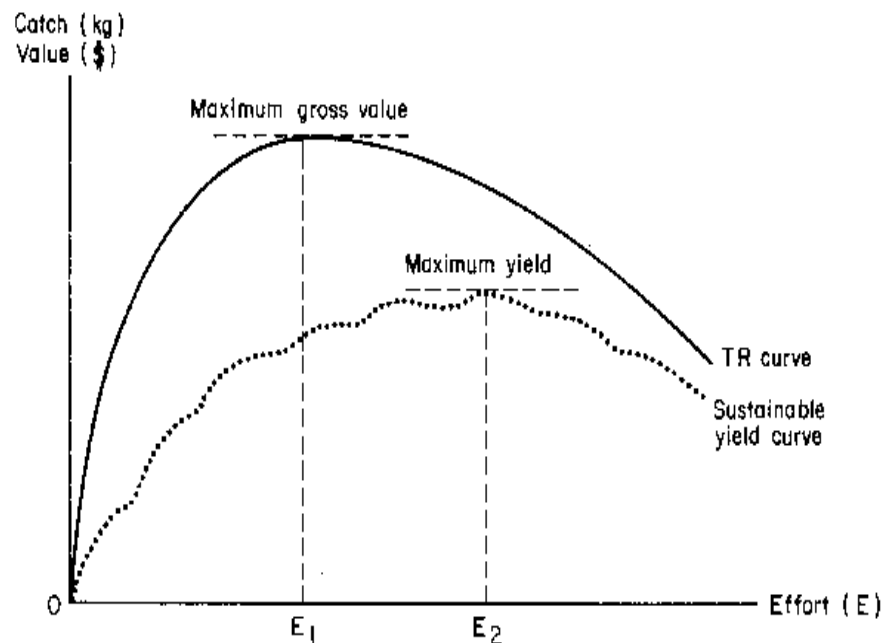


Figure 16. Gross economic yield multi-species (From: Panayotou, 1982).

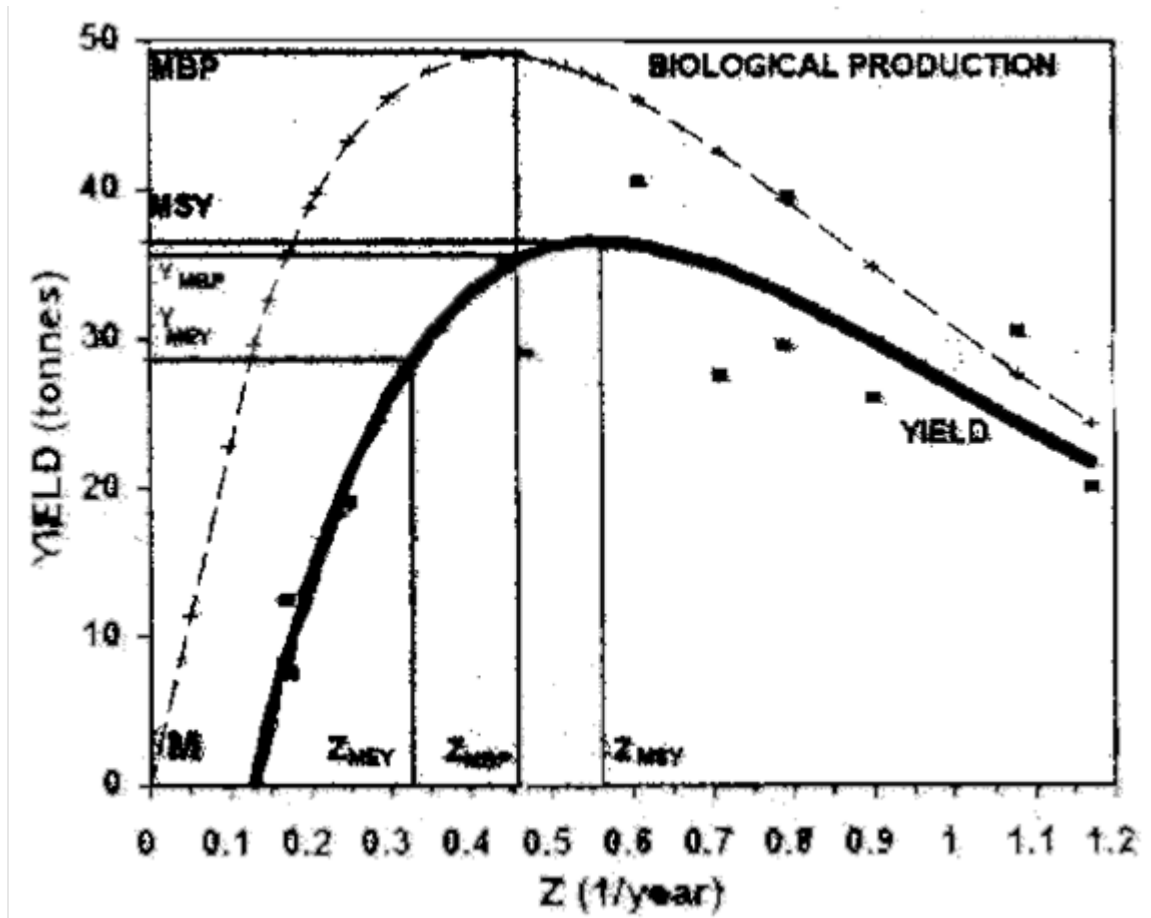


Figure 17. Bio-economic yield and production curves (From: Seijo et al., 1998).

#### E. MAXIMUM BIOLOGICAL PRODUCTION

A third overlay exists with annual growth of fishery relative to stock size shown in Figure 14, reflecting biological production or a yield of biomass in Figure 17. Figure 17 shows the relationship of MSY and MEY to maximum biological production (MBP) or a yield of biomass, where what is produced is more than yield over a year period. Harvest at MBP and MSY, given population uncertainties introduce the potential for decline in biological production and yield. In Figures 15 and 16, harvest at MEY reflects a harvest management level below MSY and MBP.

Given the many variable factors involved in the salmon fishery, if all aspects affecting the salmon life history were held constant, it would be possible to approach

MSY. However, bio-economic yield and production curves are environmentally variable and the stock MBP varies run to run, year to year; not all biological production is transferable to yield. A chronic complication lies with the uncertainty of future stock availability as fishery harvest tendencies ensure that long-run results are usually dominated by short-run profit motives (Siejo et al., 1998). For the Chinook salmon fisheries, demand grew to exceed wild biological production supply, while the fishery was being harvested, effort in excess of MSY, and most likely MBP. This resulted in a short run drive to harvest at unsustainable levels. Decrease in total biomass directly degraded biological production potential (Figure 18).

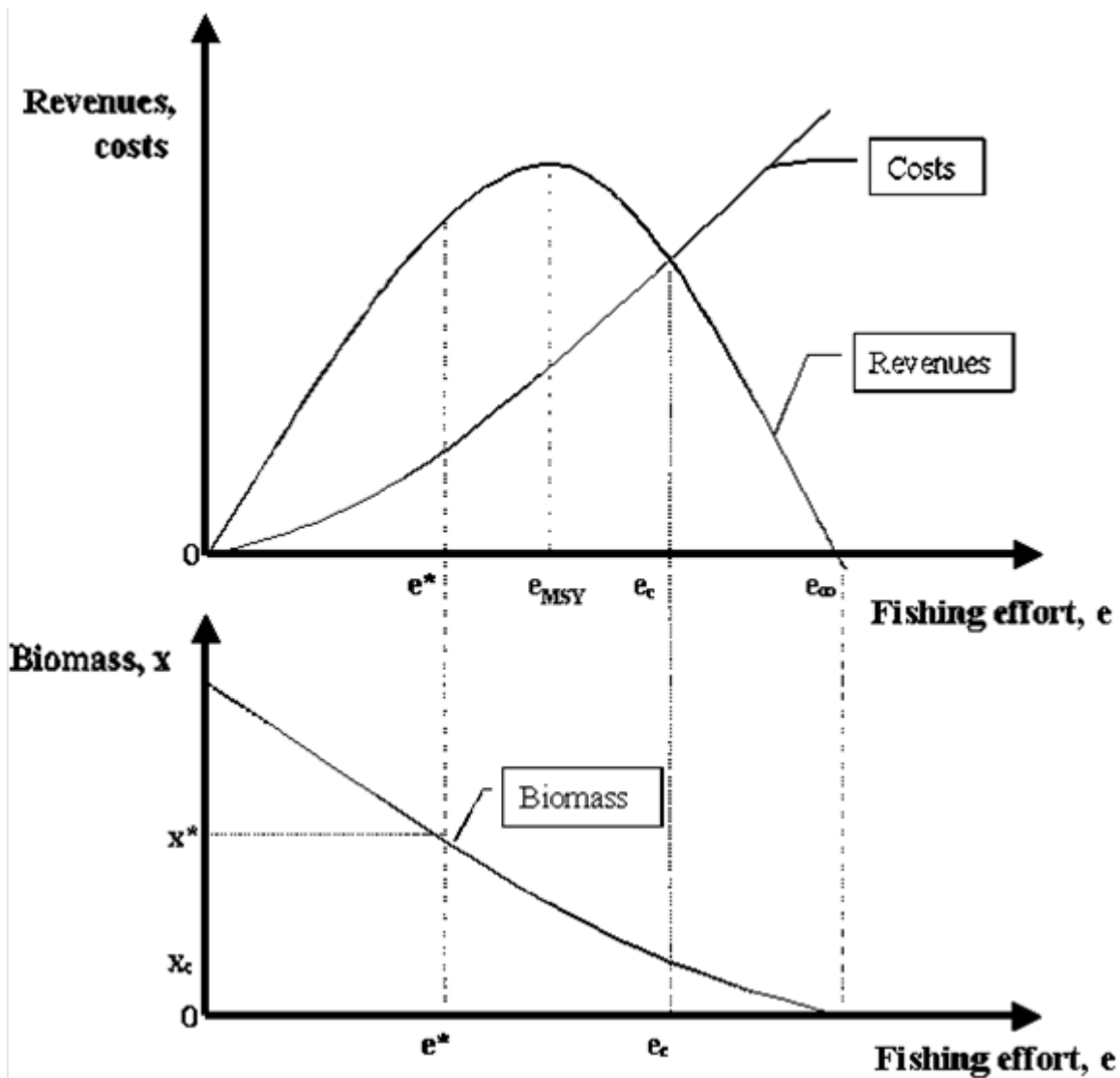


Figure 18. Fishing effort v. biomass & revenues/costs (From: Panayatou, 1982).

Figure 19 reflects the Gordon-Schaeffer Fishery Production Function and the relationship between fishing effort, cost, revenue, and biomass (Gordon, 1954; Panayatou, 1982). Gordon and Schaefer's work, integrating bio-economics, biological science and microeconomics, describes more effectively the relationship between revenue, cost, profit, MEY, and MSY as effort increases. Harvest at MEY, requires less effort and more stock is available, with a greater profit potential. Harvest at MSY requires more effort and more cost, with reduced profits. Harvest in excess of MSY, where total costs equals total revenue, more effort is required with less available stock. Without a rise in catch price and a limited catch allowed, fishers move toward or actually operate at a loss for effort expended.

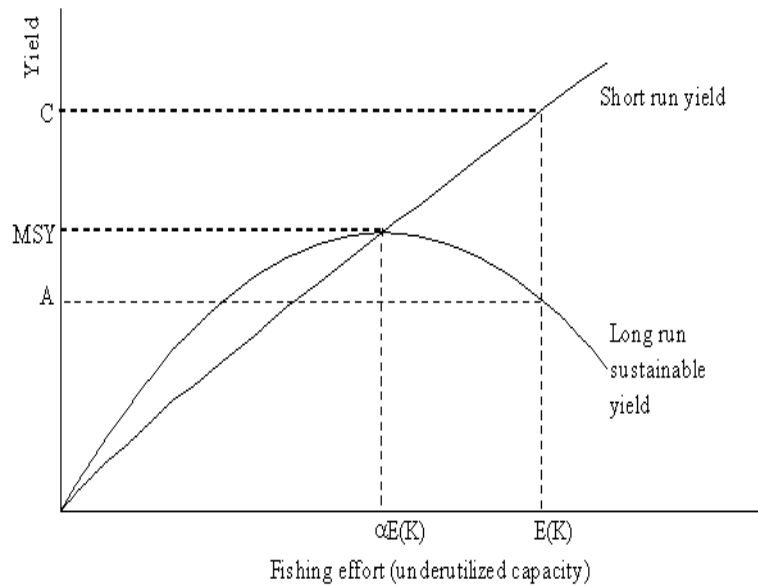


Figure 19. Stock size growth replenishment capacity (From: FAO, 2004).

## F. REDUCING HARVEST EFFORT

Reducing fishing effort to manage fishers reflected a late-developing awareness in fisheries management, since achieving a sustainable equilibrium was previously assumed to be self-regulating in an open-access fishery (Hilborn et al., 1995). The challenge, as noted earlier, is that individual fisher micro-motives do not characteristically reflect fishery macro-motives that enable recovery back to a sustainable MEY, MSY, MBP

equilibriums. As stocks decline, fishery management initially tried to reduce effort by decreasing the number of boats, how much is caught by what gear type, and/or shortening the season length. With a declining fishery, there is excess capacity and reduced utilization in the fishing vessel fleet. Technology improves fisher efficiency and catch for unit of effort decreases for the fisher. Fishers with technological or regional advantages may be able to endure despite the decline. As a result, management focus requires further constraints to curb improvements in fisher efficiency.

Figure 19 shows the relationship between effort and biomass, and how profits in a fishery reach a maximum. As a fishery is overfished, the declining biomass results in an increase in fishing effort. Costs of additional units of effort rise as fishing effort increases and revenues decrease. Harvest, in excess of MSY, offers a higher short-run revenue yield at the expense of delayed fishery management. For the majority of the West Coast fishery's history, catch information was not available in a timely manner. As a result, stock managers were consistently unable to foresee major stock crashes, much less prevent them. In turn, fishing dependent communities grew, hastening eventual decline and collapse of regional coastal fleets (Cochrane, 2002).

Overcapacity in the salmon fishery occurs when too many fishers, seeking short-term profit, compete for a smaller share of a declining fish stock. This situation is inefficient long term, but not always for the fisher with a shorter time horizon of maximizing present revenue and profit. The result puts additional pressure on the declining stock and threatens species recovery, reducing fish catch and population further (Grafton, 1996). The sustainable yield of a fishery, however, will be an attainable goal only when the number of fishers is limited by regulation and they act in concert (Schelling, 1978). In multi-species, multi-stakeholder fisheries, like West Coast salmon, reducing or balancing the quantity of the catch is not a simple fix. Balancing stakeholder priorities interferes with managing stock restoration, as catch already has been reduced to a comparative unsustainable level for the given harvest effort.

## **G. VESSEL MANAGEMENT**

When full fishing fleet capacity is aggregated at  $C$  and  $E(K)$  (Figure 19), one finds that short-run yield exceeds the maximum sustainable fishery yield. When pressure is placed on fleet utilization within a fishery, each fisher seeks to maximize their short-run share. This results in declining long run sustainable yield at those effort and yield levels, as shown in Figure 19. When allowable catch is reduced below a seasonal threshold and shares are limited, this will typically reduce profitability of regional fisher communities operating at low profit margins.

Individual fisher and industry responses result in preferring short-term adjustments to sustain operations and prevent regional fisher collapse. Lowering catch level, in lieu of a moratorium, ( $A$  and  $E(K)$ ) postpones and fails to rebuild stocks from current levels (L. G. Anderson, 1976). Some fishers have limited ability or solvency to adapt to declining catch, the least efficient or less profitable fishers are forced out of the industry.

In Figure 20, the fleet size  $K$  (assuming full utilization) represents catch effort or number of vessels in the fishery and the fleet's relationship with sustainable yield. The larger the fleet size, the closer to full utilization. If the fleet size has fewer vessels that are more technologically efficient that also approximates full utilization employed for the harvest. If a fishery begins harvest at fleet size ( $K^{**}$ ), the harvest yield does not exceed MSY. MSY is associated with a fleet capacity ( $K^*$ ), which leads to a decline in sustainable yield, provided MSY is accurate. In excess of MSY, fleet capacity is utilized for short-term gain, but subsequently there will be a decrease in available yield and inadequate biomass to sustain fleet size at full utilization.

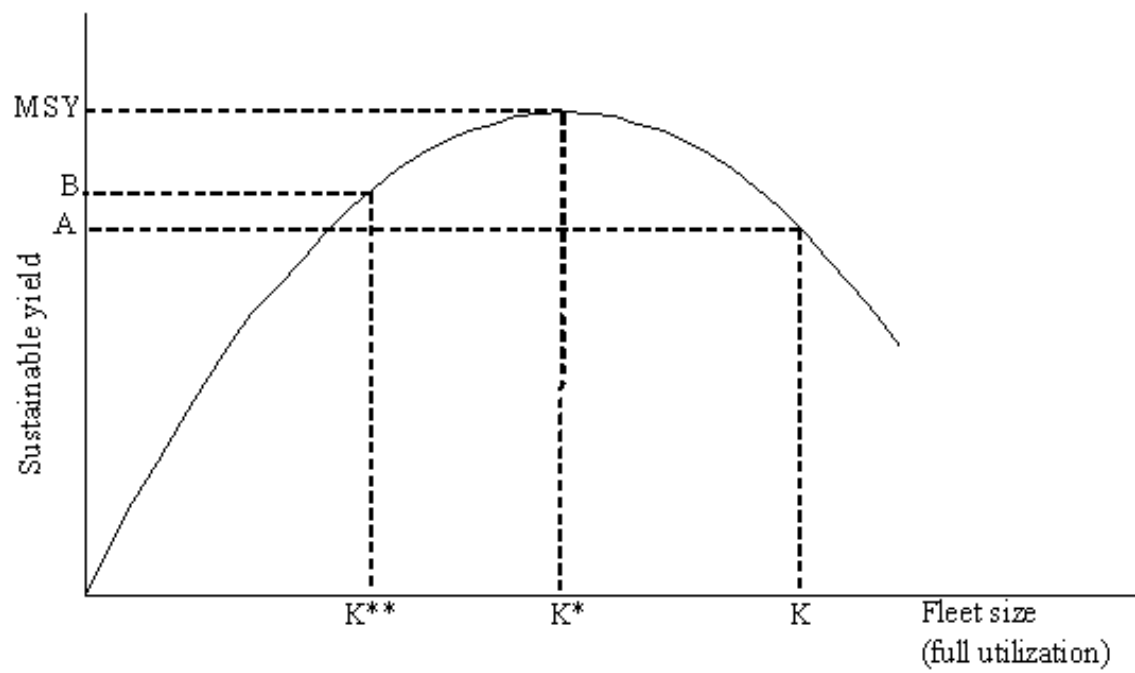


Figure 20. Example of single species, single fleet fishery (From: FAO, 2004).

## **IV. DATA AND METHODS**

A wide range of historical Pacific commercial Chinook harvest data were collected from several sources, dating as far back as the mid-19th century. Data are derived from National Marine Fisheries Service (NMFS), Pacific Fishery Management Council (PFMC), and the Pacific Fisheries Information Network (PacFIN), the nation's first regional fisheries data network for Chinook salmon fisheries off the coasts of Washington, Oregon, California, Alaska, and British Columbia. Data were also gathered on British Columbia commercial catch statistics reports from Regional Data Services, Fisheries and Oceans Canada.

Annual aggregated commercial catch was obtained from PFMC All Species Reports, for the years 1981 to 2007, for California, Oregon and Washington. Actual catch in the Chinook fisheries is measured by actual ex-vessel revenue data collected by each state. Commercial effort is measured in ex-vessel value, which is the gross value paid to commercial fishermen for round weight of salmon harvested. Round weight is the full fish. Dressed weight is a smaller value for cleaned fish. PacFIN data is finalized for the years 1981–2007. However, there may be some small differences over time, between previously reported numbers and what is currently on the PacFIN website, as PacFIN periodically refreshes its files to correct discovered errors or capture unexpected late landings receipts. Data include fish prices, tons caught, and value caught. PacFIN provides both landed and round weight estimates. Salmon are usually landed in dressed form, the round weight equivalents were used to align to other fisheries, where landings are made in the round.

Chinook consumption is tracked in five major market categories: 1) the fresh and frozen markets of the European Union, 2) Japanese markets, 3) United States markets, 4) the canned salmon market, and 5) other smaller markets (J. L. Anderson, 1997). Automated data summary programs from the Fisheries Statistics Division of the National Marine Fisheries Service (NMFS) were used to gather and summarize U.S. commercial salmon landings, imports and exports from 1975 to 2007. The NMFS numbers are

actually derived from PacFIN data. NMFS adds data for each year as they become available. NMFS does not systematically refresh prior year numbers when PacFIN refreshes catch data files. Available data shows recent trends in the fishery and can be used to assess the resultant impacts on both long and short-term sustainability.

Using this data on catch, ex-vessel price, imports and trade, this research is a review of the pressure of long and short term historical production data and trends, which reflect the status of the fishery econometrics, bio-economics, and sustainable yield concepts used to estimate demand curve effects as a result of effective marketing campaigns, changes in price, and increases and decreases in supply.

### A. COMMERCIAL HARVEST

The metric tons of wild Chinook salmon landed are shown for the total US, Figure 21, as well as California, Oregon, Washington, and Alaska, Figures 22 and 23, which combines California, Oregon, and Washington as West Coast states. These figures show the declining trends in harvest catch from 1950 to 2007.

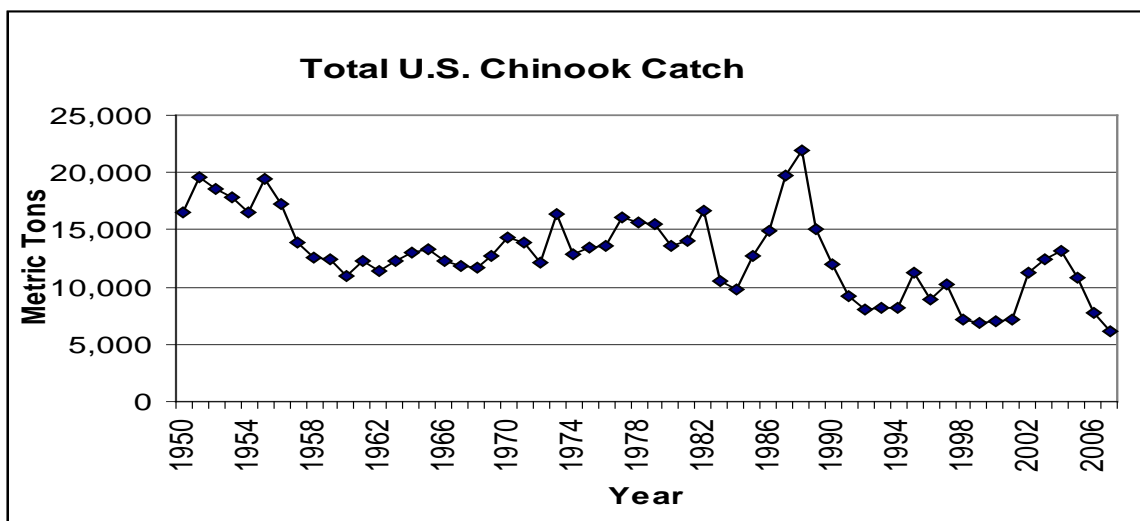


Figure 21. Total U.S. Chinook catch (From: NMFS, 2008b).

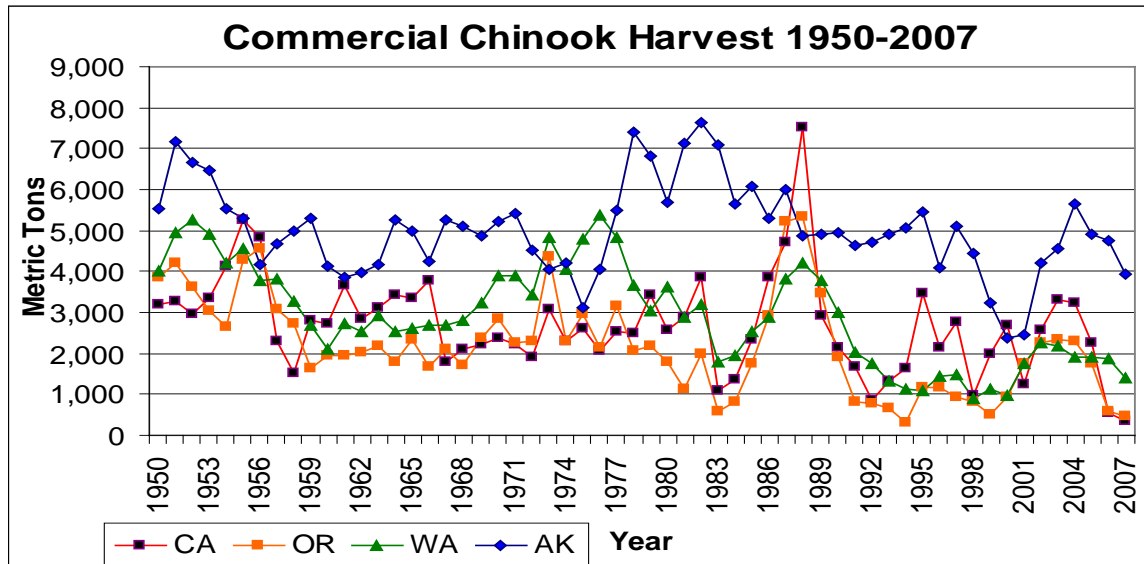


Figure 22. Western state commercial Chinook harvest 1950–2007 (From: NMFS 2008b).

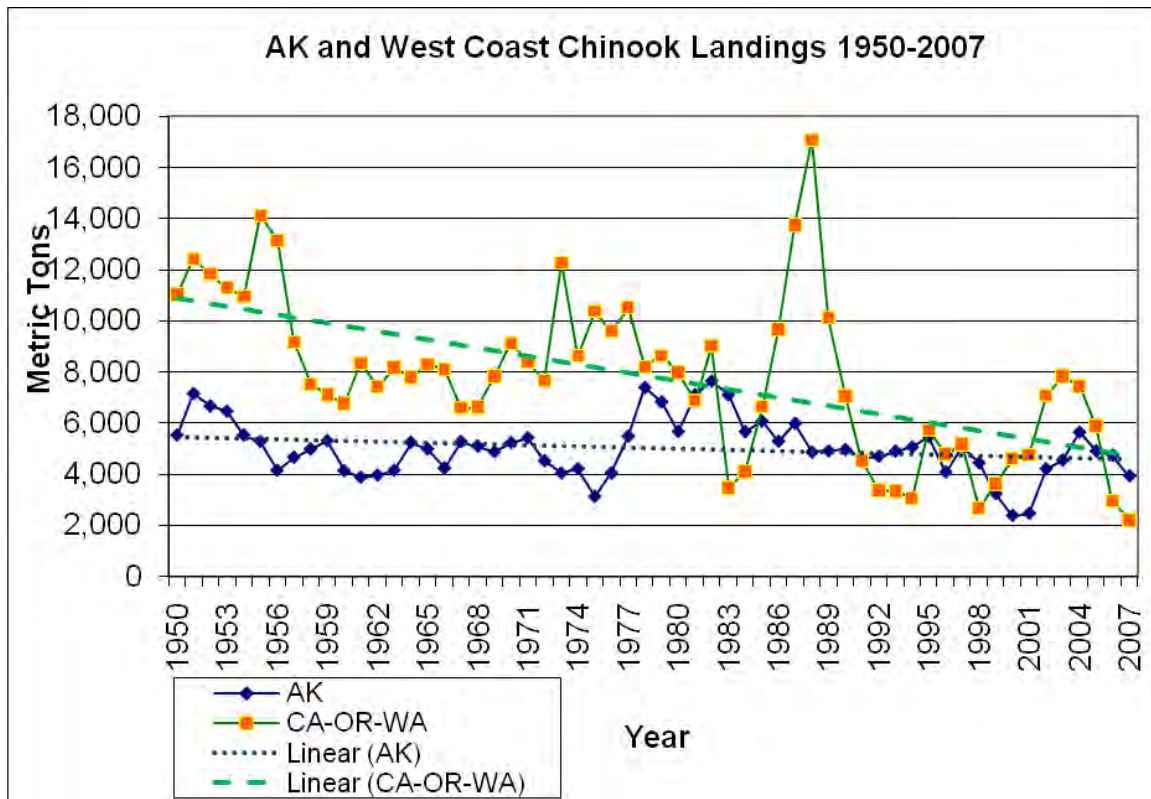


Figure 23. Harvest of AK and all West Coast Chinook 1950–2007 (From: NMFS, 2008b).

Over the period 1950–2007, shown in Figures 22 and 23, Alaskan Chinook stocks have consistently harvested at higher levels than other western states. Alaska’s high production from the mid-1970s to the late 1980s has been attributed to favorable ocean conditions, enhanced hatchery releases and reductions in foreign fleet pressure (Beamish & Bouillon, 1993; Coronadao & Hilborn, 1998). As the U.S. fleet moved offshore, catches stabilized until the mid-1980s. Aside from the late-1980s spike in harvests, California, Oregon, and Washington landings have declined over the period 1975–2007. The peak harvest experienced in California and Oregon, shown in Figure 24, peaked at twice-commercial harvests over 1970 to mid-1980s levels. The decline following this spike indicates that this harvest was not an indication of stock improvement, but rather fishers harvested well in excess of all sustainable yields.

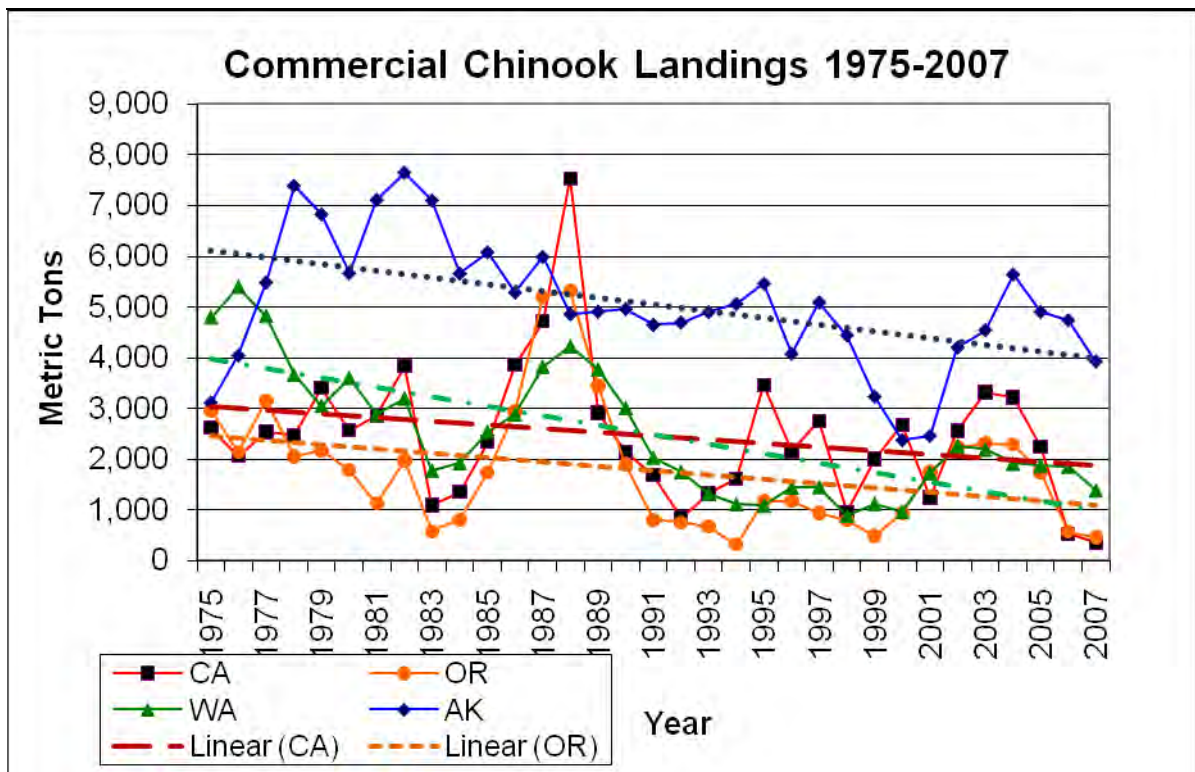


Figure 24. Trend in commercial Chinook landings 1975–2007 (From: NMFS, 2008b).

The linear downtrend in ex-vessel round weight of western states harvest over period 1975 through 2007 (Figure 24) also indicates downward trending supply. Chinook

salmon harvest levels are below historical levels, with harvest ceilings in effect since 1981. Alaskan total catch over that same period of 167,000 metric tons is more than two times the Washington and California totals and nearly three times that of Oregon. Recorded harvest peaks from 600,000 metric tons to as high as 900,000 occurred in 1920s, 1930s, and 1940s, prior to the construction of dams. Between 1975 and 2007, harvest levels are less than 1% of historical levels.

Catch trends have also varied among bordering regions in North America. The reliance on more catch derived from western Alaskan sources represents increased pressure on wild stocks. In the Bering Sea and Aleutian Islands, Chinook bycatch in pollock and groundfish fisheries has resulted in management to protect the valued stock. North American commercial fishermen catch about 15 times more Chinook than Asian countries; Japan high seas fisheries also capture North American Chinook. The decline in the West Coast Chinook fishery is also affecting British Columbia's harvests, which have been in decline since the early 1980s to a fraction of their former abundance. Figure 25 depicts the decline of British Columbia Chinook fishery and portends a more dire future ahead for import and market prices, as Canada has historically led the United States in measures toward preserving fisheries.

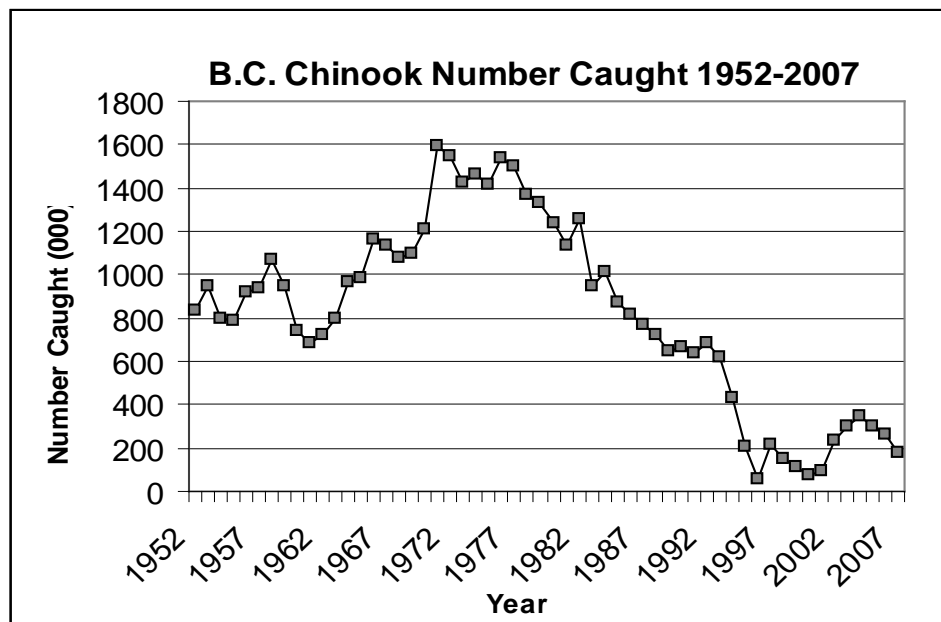


Figure 25. British Columbia Chinook catch 1952–2007 (From: Fisheries and Oceans Canada, 2008b).

Ex-vessel revenue for Chinook landings were relatively stable over the period from the 1950s through the early 1970s, when measured in constant dollars indexed to 2006 (Figure 26). Ex-vessel revenue is the quantity of fish landed multiplied by an average price received at the first point of sale. This captures the immediate value of the commercial harvest, but does not reflect subsequent revenues generated within the supply chain.

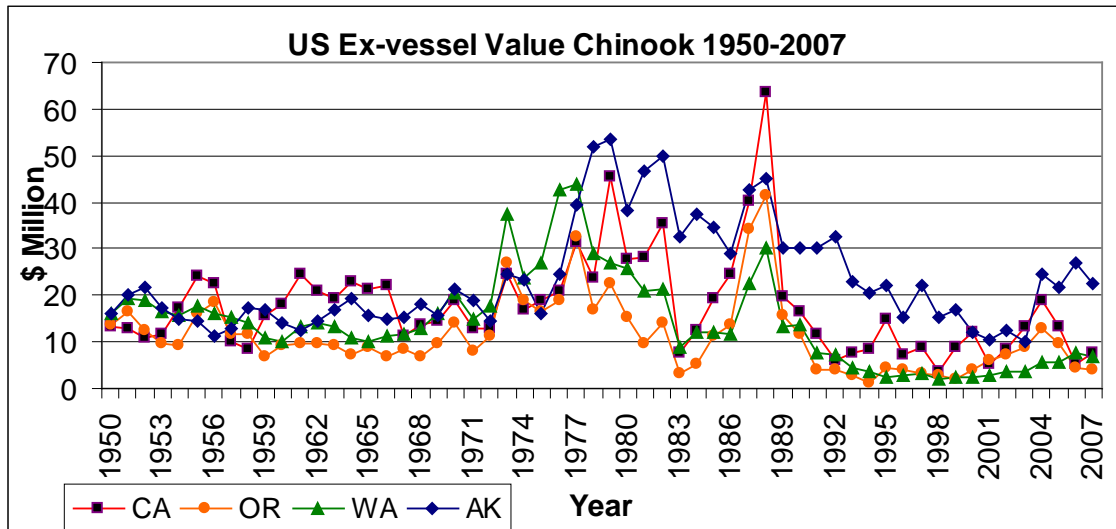


Figure 26. Western U.S. ex-vessel value from Chinook harvest (From: NMFS, 2008b).

From 1950 until the late 1970s, the West Coast Chinook fishery combined consistently landed more catch than Alaska. As more fish were harvested to supply export demand, ex-vessel revenue increased into the early 1980s. Overall, however, West Coast catch decreased and for the first time was exceeded by the Alaskan catch in the early 1980s. The Oregon and California trend in the 1980s and 1990s is akin to a boom-bust pattern, rather than gradual adjustments; the 1988s catch was three times greater than in 1985 (Figure 27).

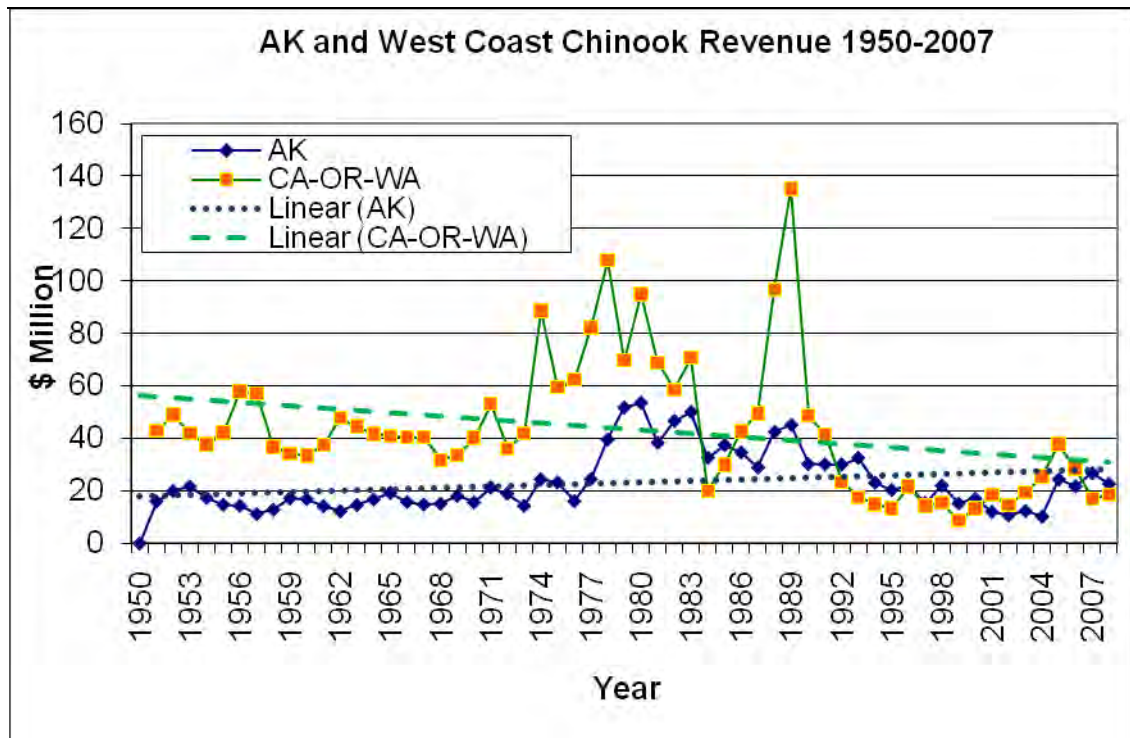


Figure 27. Chinook revenue 1950–2007 (From: NMFS, 2008b).

Alaska’s conservation of salmon is required by law under the state’s constitution, a requirement unique among the 50 states. The Alaska management system separates management authority from allocation authority. Salmon policies are aimed at sustainable yields and conservation policies define programs for protecting habitats and sustaining salmon, with priority placed on wild stocks. Further, in 1990, Alaska outlawed farmed salmon to protect native stocks from hybridization, disease, pollution, and competition for food.

Salmon stocks had been in decline until Alaska became a U.S. state in 1959 and the state took over resource management. The success of Alaska’s conservation, from 1959, is apparent in the positive trend within landings revenue, which shows the divergence in stock management as CA-OR-WA did not recognize or act. Since 1959, revenues and harvest in CA-WA-OR have declined; from the 1990s to present, there is

relative equality between Alaska and CA-OR-WA revenue. Since implementation, the ESA has been used to increasingly restrict Alaska fisheries to protect depressed salmon stocks in Oregon and Washington that migrate into Alaskan waters (Figure 28).

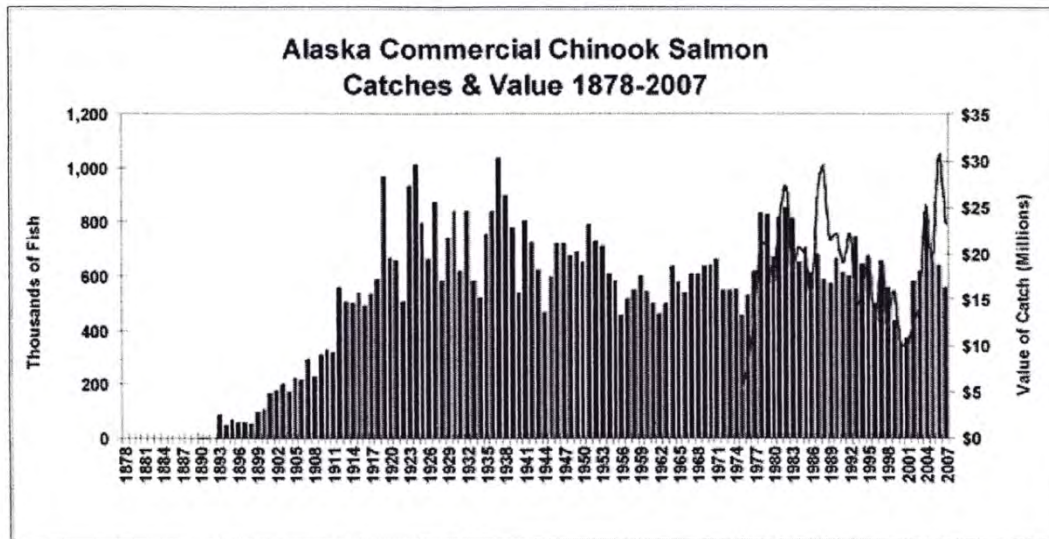


Figure 28. Alaska commercial Chinook catch and value 1878–2007 (From: ADFG, 2008).

## B. VESSEL TRENDS

Two classic problems in commercial fisheries are widely perceived to be overfishing (‘too few fish’) and overcapacity (‘too many boats’) (Clark et al., 1979). Each western U.S. state has different approaches to setting the appropriate fleet size and permits issued. Regardless, management systems have typically lagged in adjusting to declining resources.

Along the West Coast, the number of permits and active participating vessels in the troll salmon fishery have declined since 1979, from over 9,000 vessels to less than 1,000 vessels in 2006. In Oregon, a limited entry system was adopted in 1979, based upon the number of vessels landing salmon in Oregon in 1978. Prior to the 1980 season, ocean troll permits were not limited in Oregon. The number of vessels and permits

precipitously declined from 1980 until 1985. The number of troll permits issued did not change until reduced by 25% in 1993 and by one-third in 1995 (Figure 29). There has been a steady decline in vessels and permits since that time.

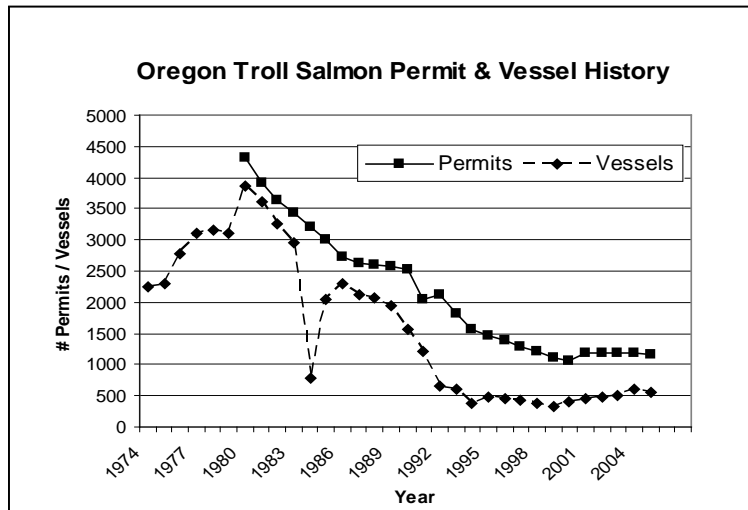


Figure 29. Oregon permit and vessel history (From: NMFS, 2008b).

In California, salmon vessels declined from nearly 4,000 to around 400 vessels between 1981 and 2006 (Figure 30). This has occurred even though 1988 California legislation authorized new permits if total permits fell below 2,500. No new permits were issued through end of 1999, with a decline to 1,550 permits in 2005. In Washington, there is currently no set number of licenses. Buyback programs, however, have reduced the size of the fleet to around 100 vessels.

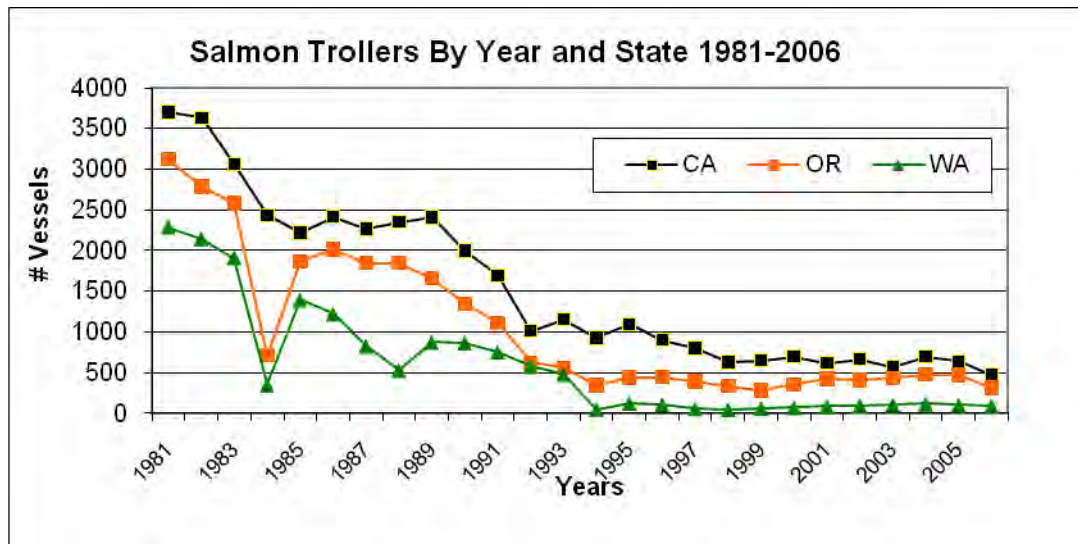


Figure 30. Salmon trollers by year and state 1981–2007 (From: NMFS, 2008b).

The number of troll trips correspondingly has declined with fewer boats and fewer fish. Salmon fishers can be low-income operators. Fishing capacity at this level may only be used on a part-time basis, but is not withdrawn completely from the fishery. If fish stocks rebound and price increases, this may induce a return of the sidelined capacity without further limitations. Once a vessel is owned, operating costs to stay in the industry are low. With a permit system capped, fisher attrition occurs over time, as the number of permits used versus unused among active boats consolidates due to transfers. Fishers exit as break-even costs dictate over multiple years of stock decline and with growing vessel maintenance and upkeep costs.

The decrease in supply of West Coast in the both the United States and Canada placed the salmon industry in a state of collapse. Efforts to revive a sustainable fishery requires improvement in management practices and enforcement. Government action has been to limit catch or close the fishery. These measures create an upper limit on the amount of fish supplied. Limited supply encourages competitive fishers to attain this upper limit of catch to offset their incurred fixed costs for the effort. Limited supply also further pressures the salmon fishing fleet. As boats are unable to operate with their catch is constrained, the size of the fleet decreases, as profits become insufficient to all operating and fixed costs.

As Figure 31 shows, the impact of the supply shift on price and quantity depends on the elasticity of demand. With inelastic demand, the quantity demanded does not respond significantly to changes in price and the demand curve is relatively steep, as in the left hand graph. In this case, the supply shift largely affects price more than total market quantity. Alternatively, if demand is elastic, and quantity demanded is responsive to changes in price, as in the right hand graph, the supply shift will have a bigger impact on total market quantity than on price.

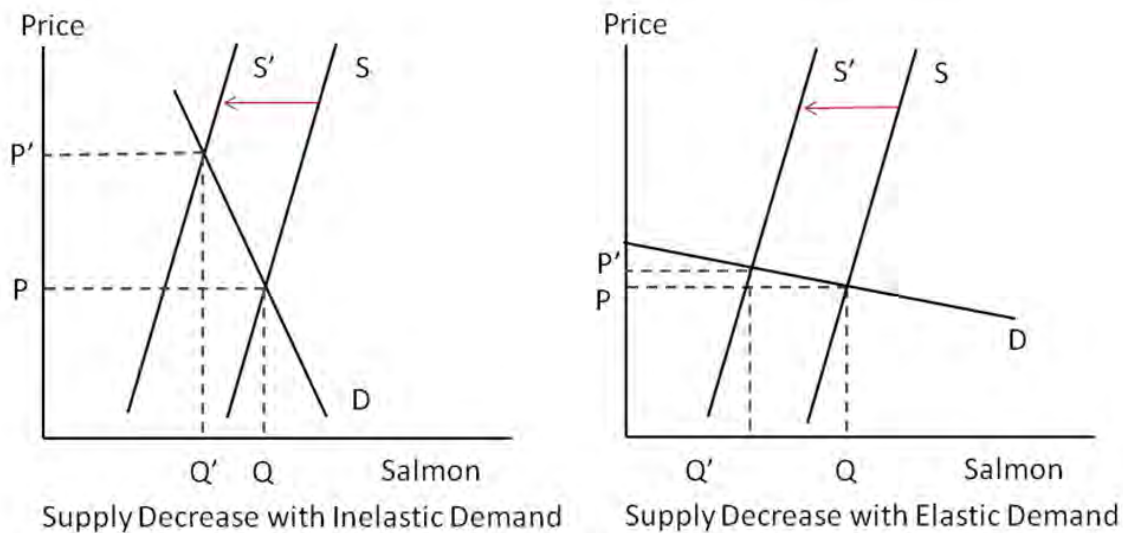


Figure 31. Supply decreases with inelastic and elastic demand.

With elastic demand and small pressure on market prices, supply decreases in the wild U.S. salmon market are not likely to affect the market for substitute products, including wild salmon imports and farm raised salmon; with no significant price pressure, profitability in competing markets is largely unaffected. If there is significant upward pressure on wild U.S. salmon prices, it will likely induce increased supply from competing products. The following section will examine historic data from the wild Salmon import and farm raised Salmon markets.

### C. SUPPLY AND CONSUMPTION

Domestic salmon prices and consumption will also be affected by changes in the supply of farmed and imported wild salmon. If salmon demand is inelastic, supply decreases in wild salmon will exert strong upward pressure on domestic salmon prices and encourage a strong supply response from farmed and imported wild salmon. If salmon demand is more elastic, the limited price effect in the domestic wild salmon market will not encourage as strong of a supply response from imported wild and farmed salmon. The interaction between domestic wild and imported wild and farmed salmon markets, with inelastic demand, is shown in Figure 32.

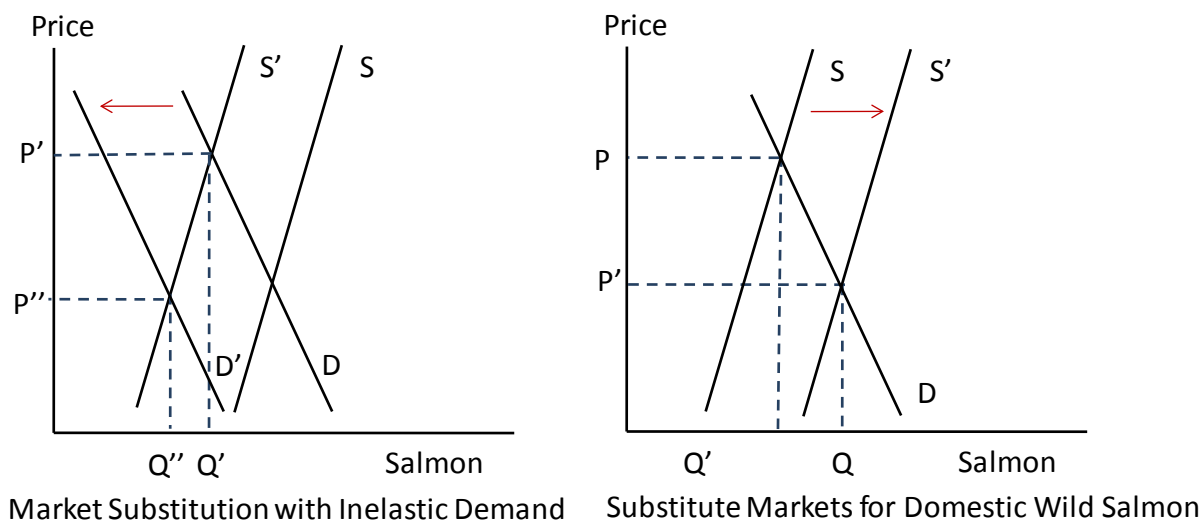


Figure 32. Market substitution.

As pictured above, the wild Chinook salmon market depends on external and internal factors affecting various stakeholders in the supply chain, consumer demand patterns, accessibility to a regionally available supply, competitive market activity, and increased reliance on imports to meet demand. Price formation in a market with farmed and wild salmon (Figure 33) provides another illustration that prices of farmed and wild salmon affect each other at wholesale and retail levels and to varying degrees, farmed and wild salmon are considered market substitutes. To some extent, prices will track one

another. If wild salmon prices rise, buyers are willing to pay more for farmed salmon. When wild salmon prices fall, buyers are not willing to pay as much for farmed salmon. (Knapp et al., 2007).

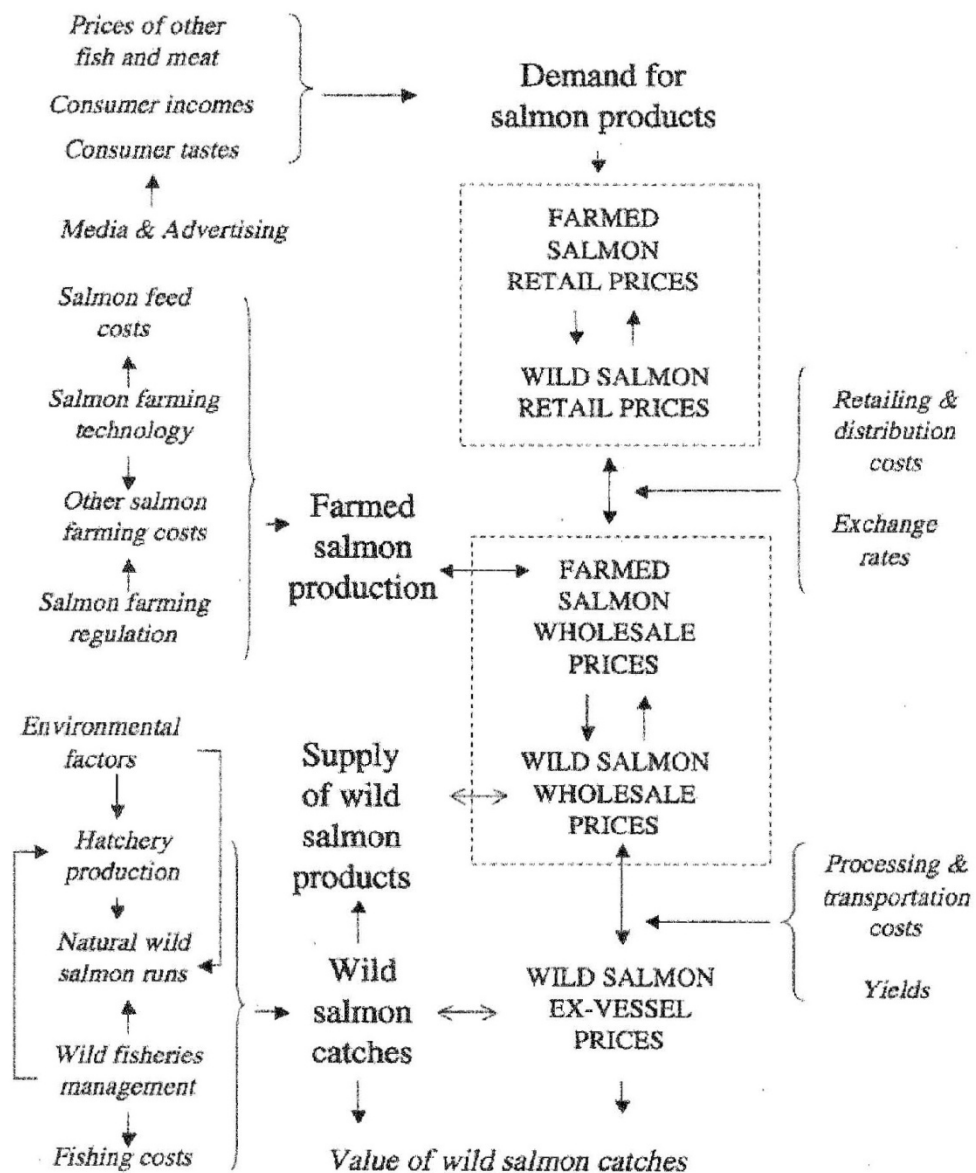


Figure 33. Salmon price formation (From: Knapp et al., 2007).

## D. IMPORTS

Overall, U.S. consumption of all salmon, both wild and farmed imports, has increased with rising overall seafood consumption. In Figure 34, which shows the value of imports of edible seafood products into the United States, the percentage of value consisting of all imported salmon products have more than doubled from the mid-1990s to 2006.

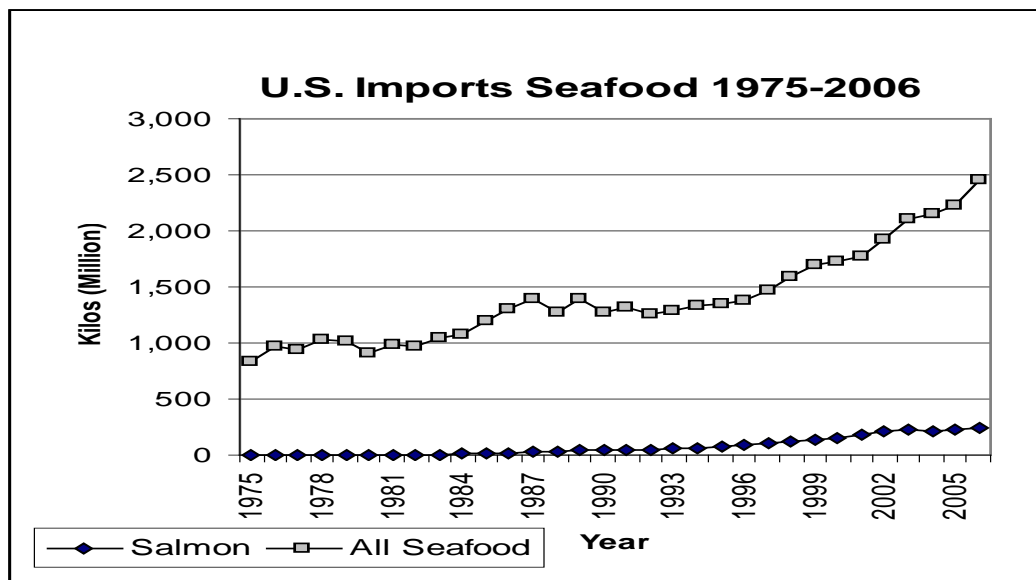


Figure 34. U.S. imports seafood 1975–2006 (From: NMFS, 2008b).

Over the period shown, countries supplying U.S. salmon imports have changed with development in aquaculture and subsequent growth of farmed salmon. With the growth of the European market from the 1990s, Norway has largely dominated farmed Atlantic salmon production, followed by growing salmon production in Chile, the United Kingdom, Canada, and Faroe Islands. Farmed imported salmon provides a year round market for a uniform fresh product that seasonal wild U.S. salmon fisheries, like Chinook, cannot adequately supply. These producers all offer lower value per pound than countries where production is relatively flat or declining (United States, Australia, France, Spain, Iceland, Ireland).

In just over four decades, the Norwegian yearly-farmed Atlantic salmon production increased from less than 500 tons in the early 1970s to 743,000 in 2008, according to Statistics Norway 2007. Figure 35 shows the total pounds of imported farmed Atlantic (Norwegian) salmon from 1989–2009, growing from 50 million pounds to 450 million pounds imported with value rising from \$200 million to \$1.3 billion industry. Prior to the 1990s, Norwegian producers dominated farmed Atlantic salmon imports.

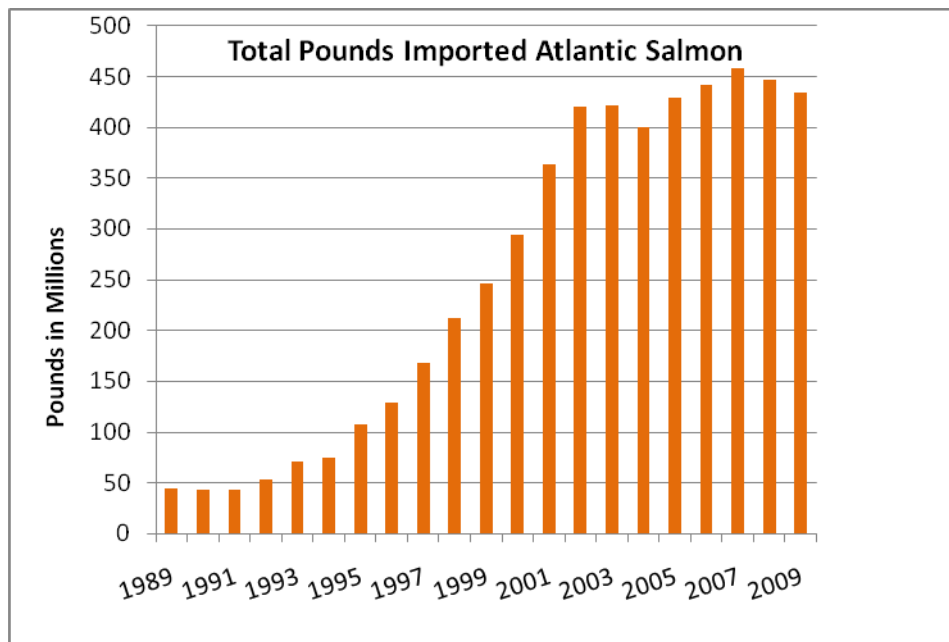


Figure 35. Total pounds of Atlantic Salmon imported by United States 1989–2009 (From: NMFS, 2009).

With growth, limits were imposed with anti-dumping and countervailing import duties and tariffs aimed to protect the U.S. market from less expensive Atlantic salmon imports, allegedly sold at less than fair market value, from Norway (later also extended to Chile, where Norwegian companies developed aquaculture sites raising Chinook salmon) (King & Anderson, 2003). Norway argued that all types of salmon substitute for one another, because, at harvest, all salmon are whole and fresh (King & Anderson, 2003). Considering that Norwegian imports, at the time, were a small part of a larger market, these imports were not likely to damage the U.S. farmed salmon industry.

Farmed salmon from Chilean and Canadian producers, however, rapidly took Norway's place, as those producers provided a farmed Chinook. Another consequence was an increase in Norwegian shipments to Japan, reducing the market share that traditionally corresponded to U.S. exporters. With the rapid entry of Canada and Chile, prices did not change appreciably (King & Anderson, 2003). The growth and competition, however, directly impacted the price of wild Chinook stock.

Prices for imported Atlantic salmon, Figure 36, indexed to 2006, reflect the recovery and increase of price per pound as U.S. imports increased and prices for farm raised salmon imported from Chile, shown in Figure 37. The rise in price per pound of farmed Chinook and Coho from Chile should correspondingly result in a higher premium price for landed U.S. wild Chinook.

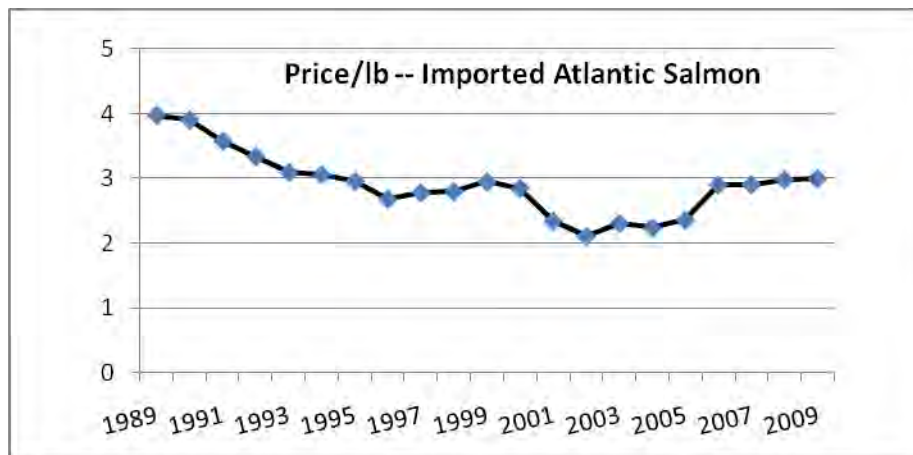


Figure 36. Average price per pound of imported Atlantic Salmon 1989–2009 (From: NMFS, 2009).

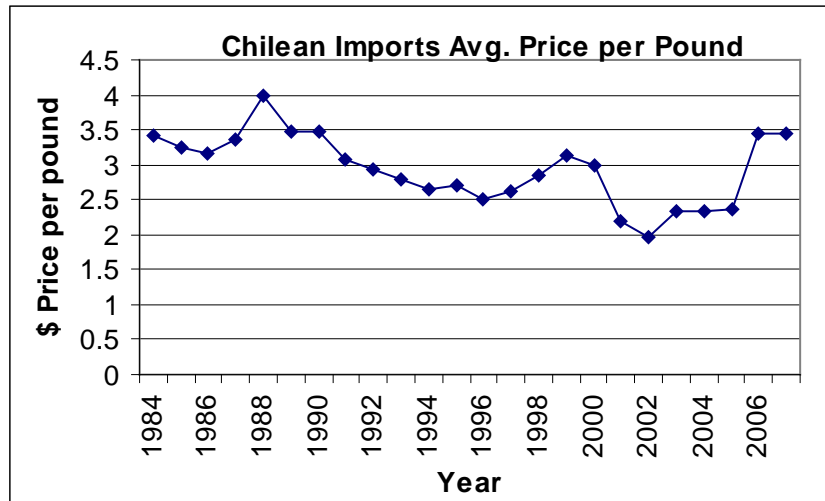


Figure 37. Average price per pound Chilean imports (From: NMFS, 2008b).

As a result of imported farmed market input, aggregate salmon supply increased from Aggregate supply1, reflecting Chinook salmon wild imports, to Aggregate supply 2, reflecting the additional farmed raised Chinook imports (Figure 38). The production of farmed salmon led to a surplus and overproduction at the original market price. As supply increased, the market equilibrium quantity increased from Q1 to Q2 and the market price of salmon fell from P1 to P2. In the short run, prices lowered with the increased supply (Figures 36 and 37). Many small Norwegian farmers went bankrupt and the industry had to be reorganized to cope with the new market conditions (Hjelt, 2000). The industry consolidation resulted in vertically integrated production over various life stages and processing. Improvements in handling and packaging of the wild and farmed fish have also improved product marketing and sales. The consolidation also allowed the Norwegian farming industry to retain its highly competitive profile in the global market (Forster, 2002). As consumers become more familiar with salmon, and as salmon becomes available in more locations, marketing and operations expand systematically. Norwegian companies have since expanded operations into other countries (e.g., Chile) providing the ability to increase supply.

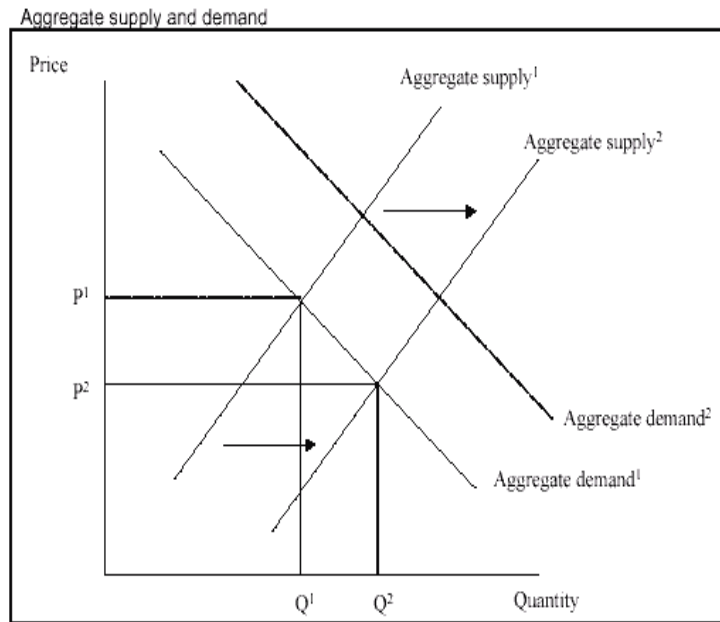


Figure 38. Aggregate supply and demand source.

During the period that the West Coast Chinook were declining, Atlantic salmon placed competitive “short run” negative pressure on salmon markets, by both increasing supply and decreasing price (Knapp et. al 2007). Canadian Chinook imports, in Figure 39, shows that Canada supplied, on average, 97% of the wild and farmed Chinook imported to the U.S. salmon fishery market between 1980 and 2007. New Zealand and Chile, while a fraction of Canada’s production, provided a significant portion of their export market to the United States. The decreasing availability and regulation of suitable salmon aquaculture sites has strictly limited production expansion in the Northern hemisphere. Chile, on the other hand, has grown with less governmental oversight, low labor and materials costs allowing the ability to compete with traditional producing countries in distant markets.

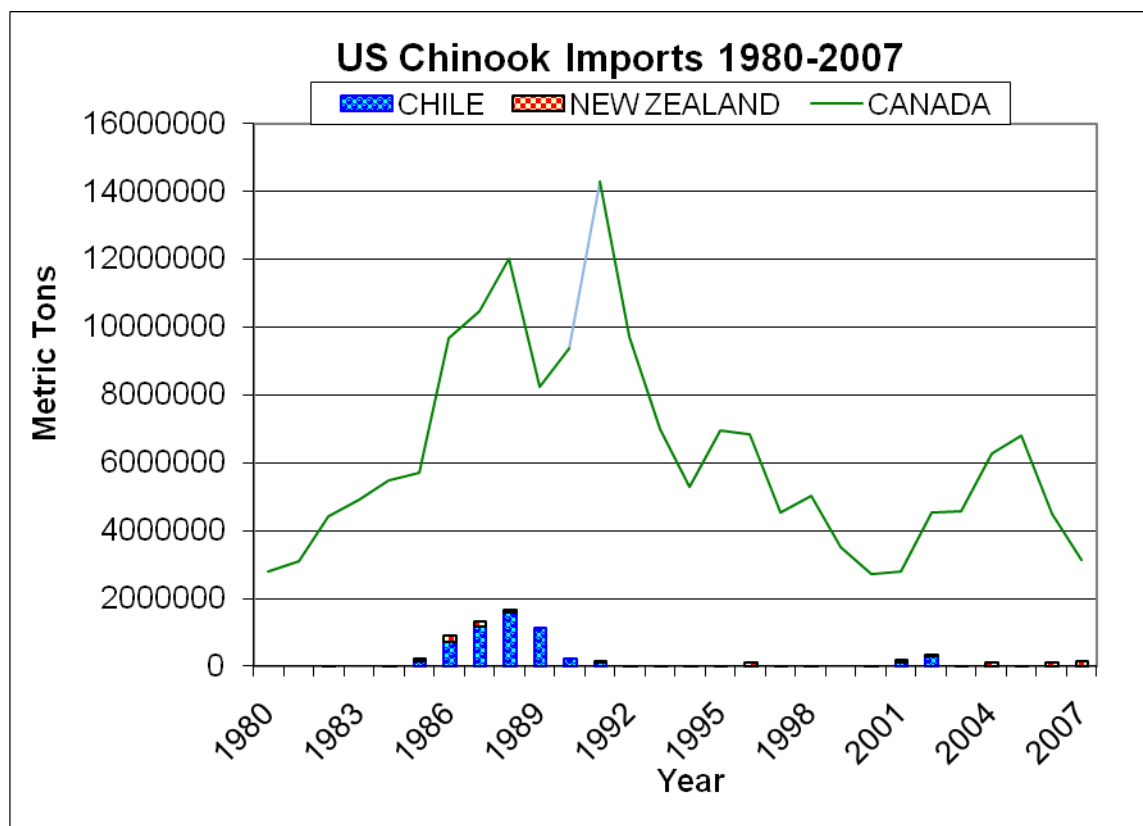


Figure 39. Chinook import sources 1980–2007. (From: NMFS, 2008b).

The United States became Chile’s principal farm raised export market in 2006, with 36% of total salmon and trout export values; overtaking Japan, which represented 32% of the Chilean market. Chilean producers introduced a farmed pinbone-out fillet in 1994/1995, which increased sales. With the rapid increases in production over the last 10-15 years, ex-farm prices have fallen. In 1989, wild salmon prices in the U.S. market began to decline with the entry of farmed Atlantic & Chinook product and lower associated supply cost. The downward trend in price lasted until 2002.

New Zealand gained market share between 2000 and 2002, during which time Canada’s market share was reduced to 93 percent. Chinook are non-native. They were imported to New Zealand in 1880 and successfully hatched; they have been marginally abundant as an introduced species. The Canadian dollar appreciated considerably against the U.S. dollar between 2002 and 2004; a condition not favorable to Canadians exporting to the United States. The production of Canadian farmed salmon also declined in 2004.

While farmed imports led to declines in salmon market price, wild Chinook salmon have consistently commanded the highest historical ex-vessel prices and premium market prices compared to other salmon species. Continued declining populations, due to climatic and human effects, ultimately affect market prices of this desirable product. Prices implicit in Figure 40 are valued in real terms (inflation adjusted). Prices have increased in nominal (actual) values from a bottom during the mid-late 1990s, early 2000s.

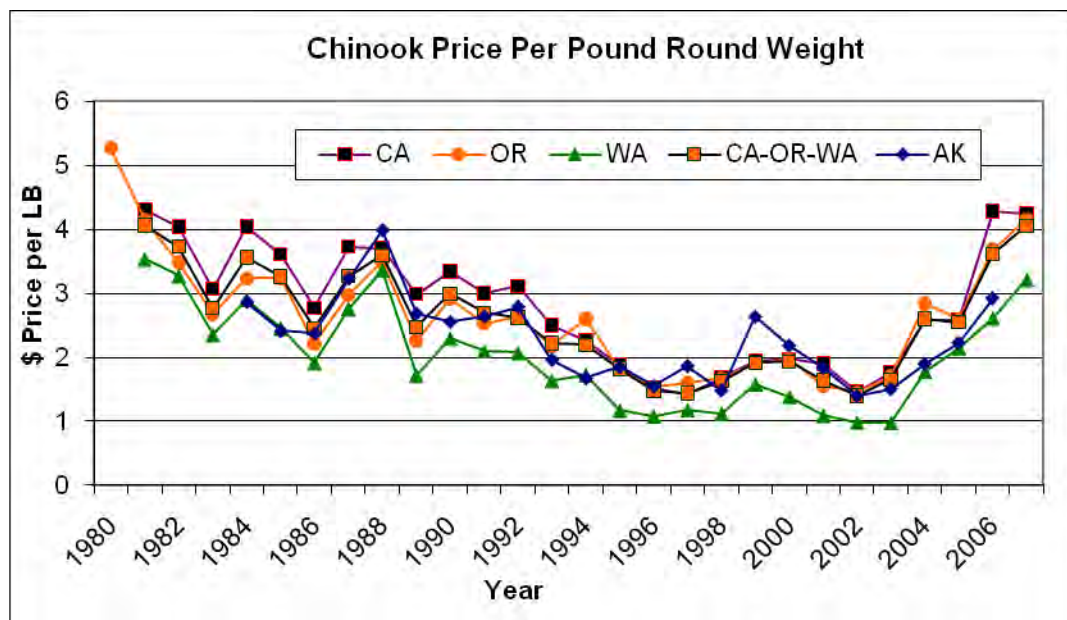


Figure 40. Average price per pound for CA, OR, WA, AK 1981–2007 (From: NMFS 2008b).

With the rise of farmed imports in the late 1980s, the average West Coast both wild and farmed salmon price began a decline and remained in a downward trend until 2003. During the mid to late 1980s increase in landings, farmed salmon was introduced to the market in significant volume. Salmon imports also began to rise in the late 1980s, leveled off in the early 1990s, and have risen almost each year since the mid-1990s. Consumer acceptance for the farmed substitute grew during this period. In 1998, the United States became a net importer of salmon for the first time, as catch from California, Oregon and Washington Chinook stocks each produced less than 1,000 metric tons

(recall Figure 23). Increased pressure on the West Coast fishery and subsequent decline occurred during a period when the market was expanding for imported farmed salmon products.

Imports of wild fresh Canadian Chinook varied over the period 1991-2007, while there is a clear uptrend in import prices. Canada is the only U.S. market supplier of wild Chinook stock. During the low import period in the late 1990s, the Canadian price per pound remained stable. In 2003, as U.S. import demand increased due to the reduction in West Coast harvest, the price of imported wild Chinook rose (indexed to 2006) along with U.S. prices. The increase in price shows a price premium over farmed for wild Chinook salmon (Knapp et. al., 2007). With the decline in wild imports 2006–2007, price per pound continued to rise (Figures 41 and 42).

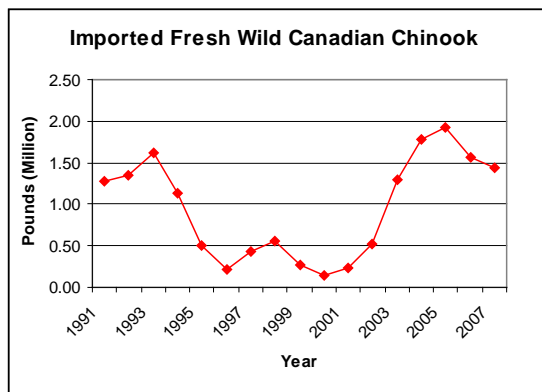


Figure 41. U.S. Canadian Chinook import (From: British Columbia Fisheries, 2008).

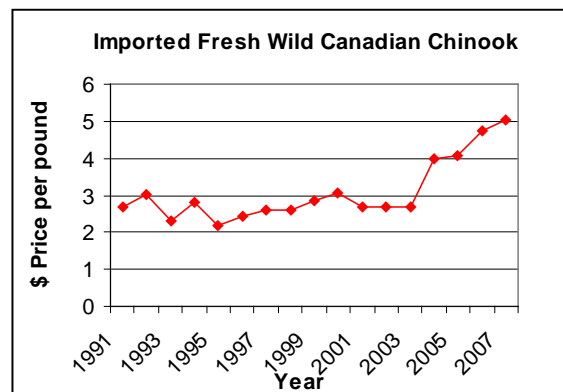


Figure 42. U.S. price per pound Canadian Chinook (From: British Columbia Fisheries, 2008).

The total western North American salmon stock includes salmon from British Columbia (BC), Canada. Between 2001 and 2007, there has been an increase in landings (Figure 43). However, the Canadian stock harvest has been in decline since the late 1970s (recall Figure 26). Wild Chinook imports from BC have also generally declined over the period, as there has been a long-term decline in aggregate west coast wild supply.

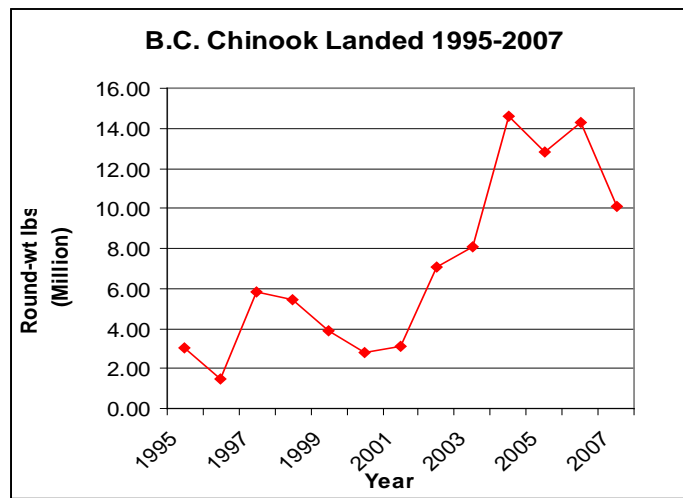


Figure 43. B.C. Chinook landed 1995–2007 (From: Fisheries and Oceans Canada, 2008b).

Domestic fishers experienced price pressure as imported and farmed salmon availability brought competition and decreased the price per pound of the average west coast wild stock. Figures 40 and 44 show the trend in prices in the U.S. Chinook market for the period 1980–2007. Average wild prices decreased in the 1990s below import prices, until 2004. Increased demand for imports also resulted in a comparatively higher market price. With the growth of seafood salmon imports, the price of imports began to rise from a period low. West Coast wild salmon prices finally rose in the early 2000s, attaining a higher price level than farmed imports. U.S. exports remain comparatively unchanged in quantity and value largely due to the decrease in the available harvest remaining for export with increased U.S. consumption and competition in the export market for what products are exported (smoked or canned) (Figure 45).

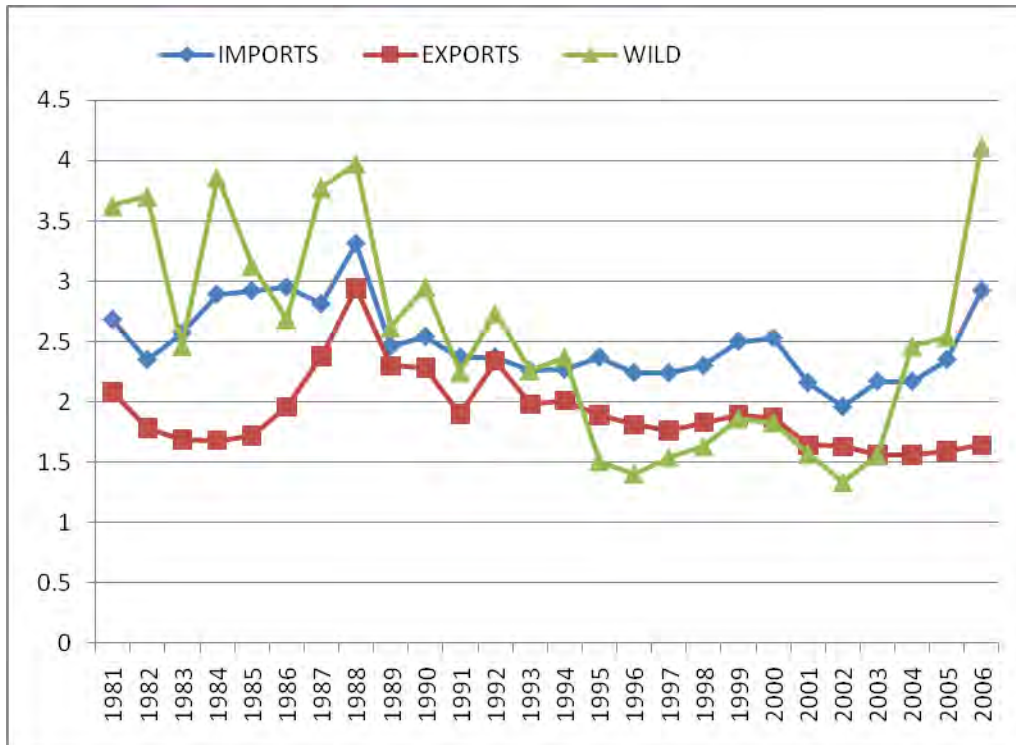


Figure 44. Average price per pound of imports, exports and wild 1981–2007 (From: NMFS, 2008a).

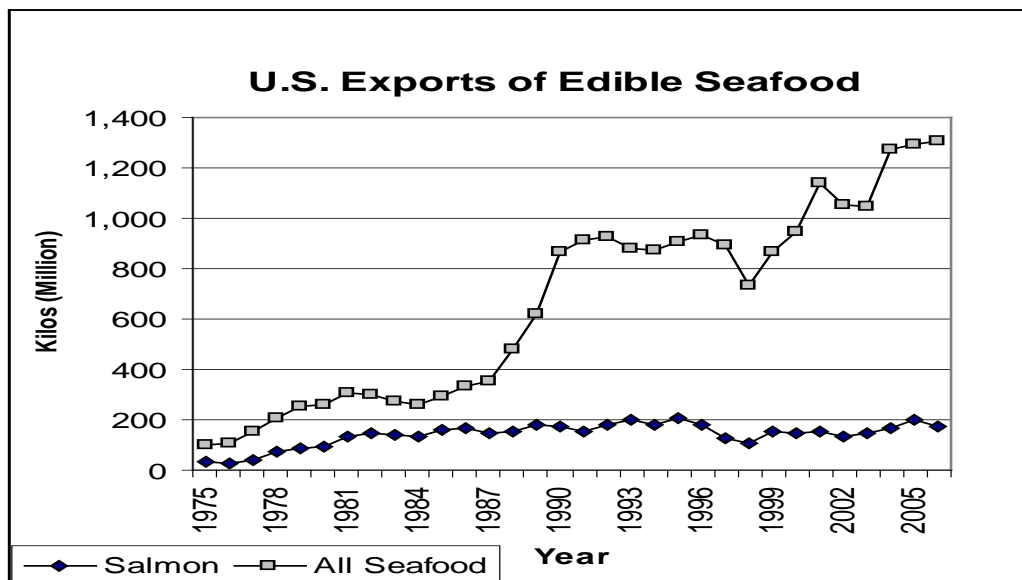


Figure 45. U.S. exports of edible seafood (From: NMFS, 2008a).

## E. SALMON EXPORTS

With declines in U.S. harvest, there has also been collapse of U.S. Chinook exports, depicted in Figure 46, unable to supply global demand. The Japanese market was at one time the largest U.S. salmon importer; U.S. exports declined with the rise of less expensive fish from Chile, as Japan began importing from that source. The growth of the European Union market experienced the largest growth in consumption, and with that growth, salmon aquaculture has taken hold in Europe. The EU collective currently consumes more U.S. salmon exports than Japan, with almost all demand satisfied by farmed salmon.

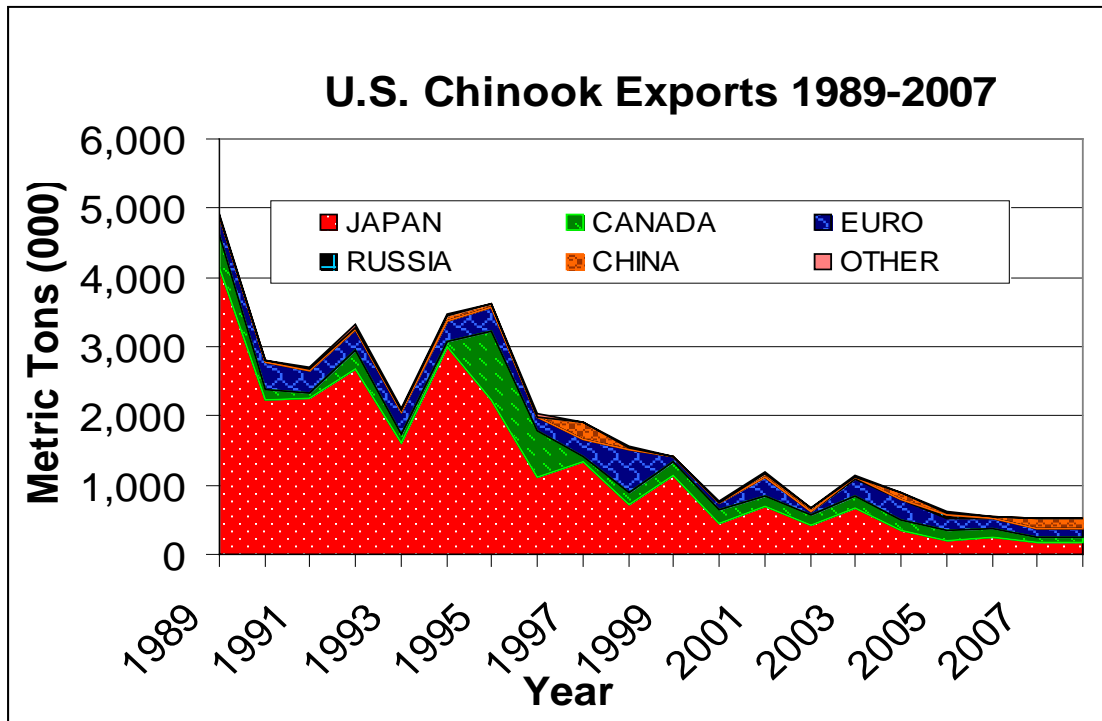
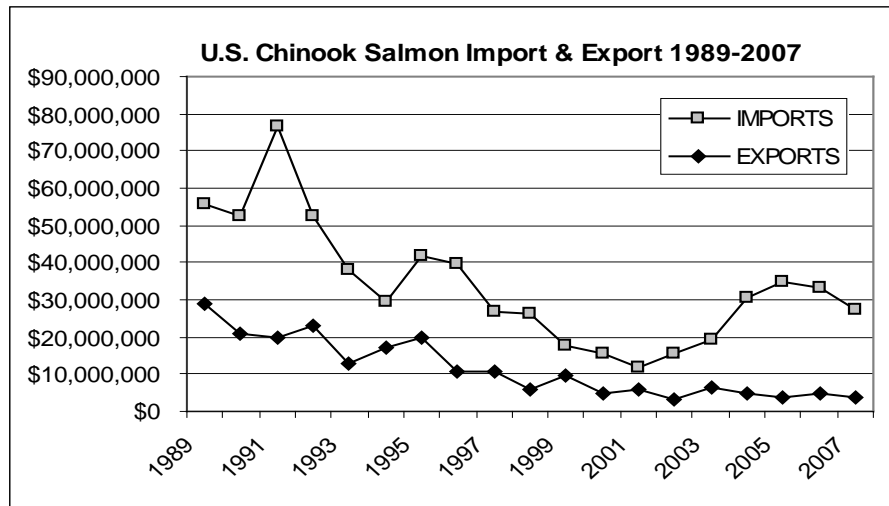


Figure 46. U.S. exports by country 1989–2007 (From: NMFS, 2008a).

## F. BALANCE OF TRADE

In the Chinook component of the U.S. salmon trade, a trade deficit reached a twenty-year low in 2001, concurrent with increased available supply (Figure 47).

Chinook exports have also been in steady decline over the period, from nearly \$29 million in 1989 to \$3 million in 2007. Fresh wild caught imports, from B.C., have increased, resulting in over a \$7 million dollar trade deficit (Figures 41 and 42). This is also coupled with declines in frozen Chinook product exports, from a 1991 \$12 million surplus to deficits ranging from \$1 to \$3.5 million between 2004 and 2007 (NMFS, 2008).



\*Prior to 1989, data is less species specific.

Figure 47. U.S. Salmon import and export 1989–2007 (From: NMFS, 2008a).

With global growth and increasing farmed salmon imports, the U.S. Chinook Salmon balance of trade began declining in the late 1980s (Figure 48). The decline in U.S. Chinook exports and rise in imports (Figure 47) reflects changes, limits, and declines in the availability of Chinook salmon stock supply. Overall, from the mid-1980s to the mid-1990s, U.S. salmon supply peaked at just over 200 million metric tons (Figure 50). In 1988, the U.S. had a salmon trade surplus of just over \$800 million (Figure 49). By 1997, this trade surplus decreased to just over \$300 million. After 1997, the U.S. trade balance in salmon products also transitioned from a net exporter to a net importer. The value of exports had reached five times the level of imports at one time; the value of Salmon imports (\$1.6B) are now more than two-times the level of salmon exports (\$.8B) (Figure 49).

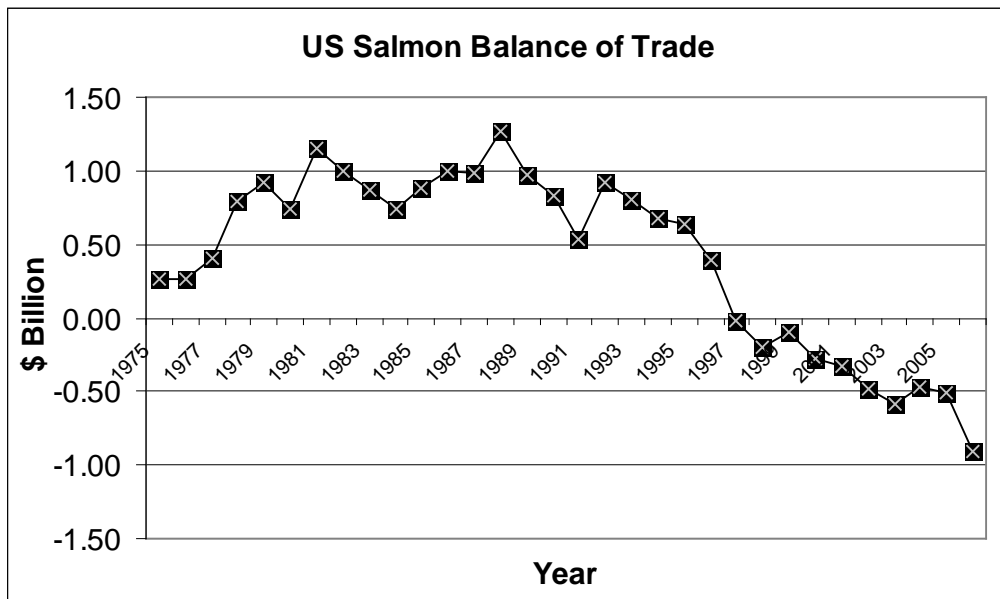


Figure 48. U.S. salmon balance of trade (From: NMFS, 2008a).

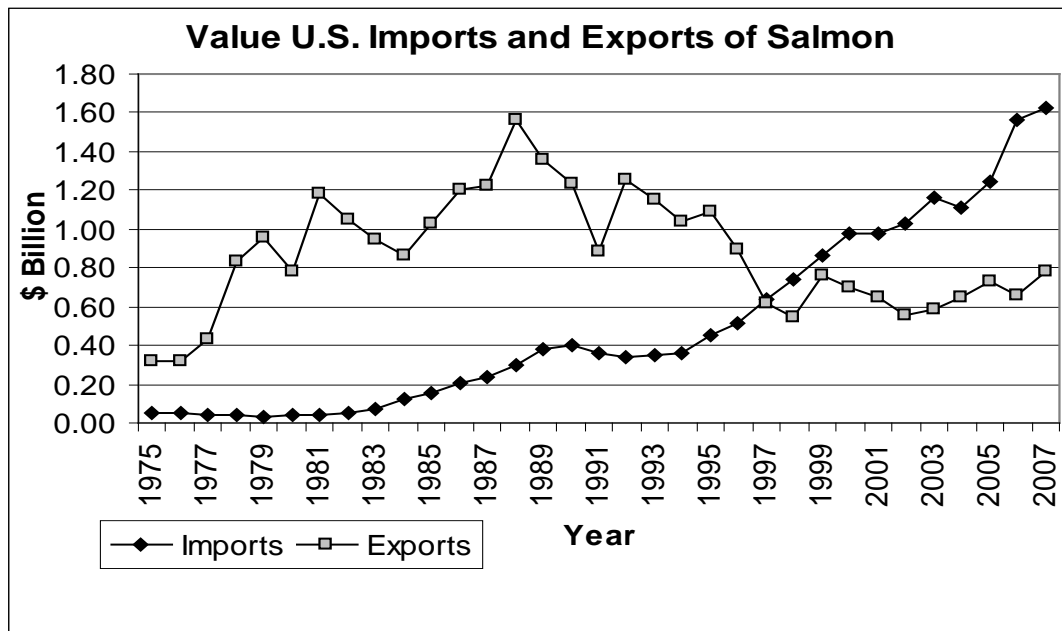


Figure 49. Imports and exports in constant 2006 dollars (From: NMFS, 2008a).

The overall salmon market has gone from its highest surplus in 1988, \$1.27 billion indexed to 2006, to a deficit of nearly \$1 billion in 2007. This is attributable to the decline and loss of U.S. wild-caught harvest, which has been limited in production and prone to greater variation than farmed sources. The majority of US supply is now imported salmon. The transition from seasonal to year-round market availability of fresh fish from inexpensive sources also significantly increased the volume of salmon imports. Imports have risen 400% between the mid-1990s and 2007, from around 50 million metric tons to 250 million metric tons (Figure 50). In the last ten years, supply has doubled since its recent 1998 low of just over 100 million metric tons to just over 200 million metric tons in 2007.

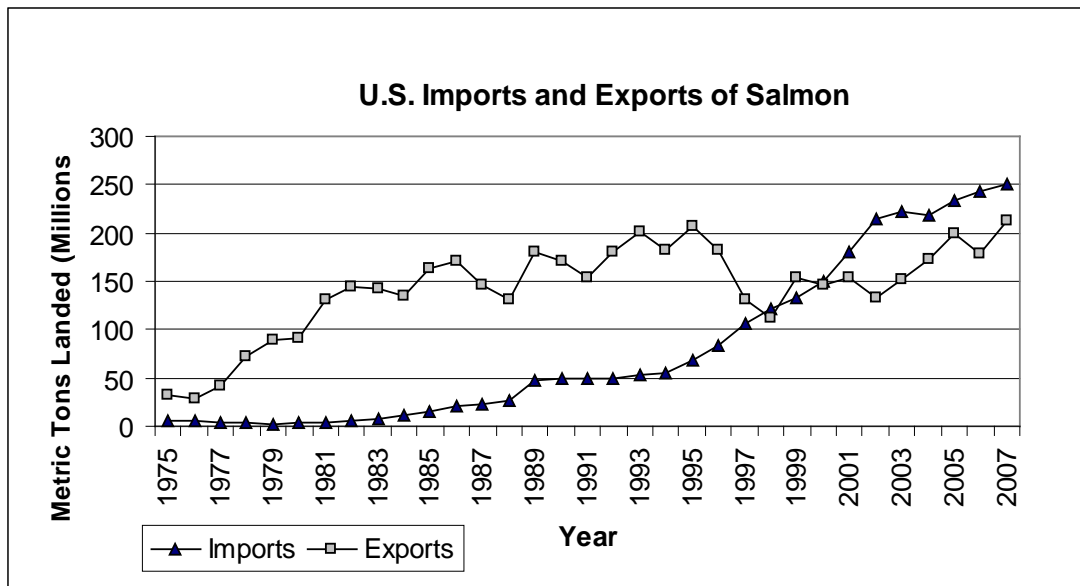


Figure 50. Imports and exports of all salmon (From: NMFS, 2008a).

The balance of trade has shifted significantly over the period. The strength of the US West Coast export, which historically was primarily buoyed by Japan importing salmon product, has also declined. With West Coast wild resources declining, market supply shifted toward the Alaska salmon and B.C. fishery supply. Further, Canadian fresh farmed fish reached an U.S. import low during a period when cheaper sources and supply increased from Chile.

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## V. SUMMARY

Between 1980 and 2006, world salmon supply more than quadrupled from 550,000 metric tons to more than 2.5 million metric tons, despite declining supplies of wild domestic salmon. With the introduction of farmed salmon in the 1980s, the ratio of farmed salmon to wild salmon has grown and farmed salmon has become the primary market supply (FAO, 2004). Consumer preferences reflect in part that imported farmed salmon is available year round, while wild salmon products are only seasonally available. As wild salmon supplies decreased, farmed fish supply increased to more than offset the declining natural commercial fishery production; and now has surpassed natural salmon production.

By the mid-1980s, farmed product began to exceed the total commercial harvest of both wild and farmed Coho and Chinook salmon. By 1983, world farmed salmon exceeded world wild Chinook harvest; by 1986, farmed salmon exceeded all world wild Chinook, Coho, and Sockeye harvest; by 1991, farmed salmon exceeded all species of Alaskan harvest; and by 1996, farmed salmon exceeded all commercial wild salmon harvest (FAO, 2006).

This situation is pictured in Figure 51. The supply of domestic wild salmon decreased, as shown in the left hand graph (labeled Initial Supply Decrease). With no changes in alternative supply sources, this would raise the price of domestic wild salmon from  $P_w$  to  $P_w'$ . However, the upward pressure on prices for domestic wild salmon increases the profitability of substitute salmon products, primarily farmed salmon, as shown in the right hand graph (labeled Supply Response). The price of substitute salmon products decreases from  $P_f$  to  $P_f'$ . As substitute products become available at an attractive price, it decreases the demand for domestic wild salmon (labeled Subsequent Demand Decrease), moderating the price effect in this market from  $P_w'$  to  $P_w''$ . This description corresponds to the changes in the domestic wild and farmed salmon markets, as well as the price for domestic wild salmon (recall Figure 40) through the early 2000s.

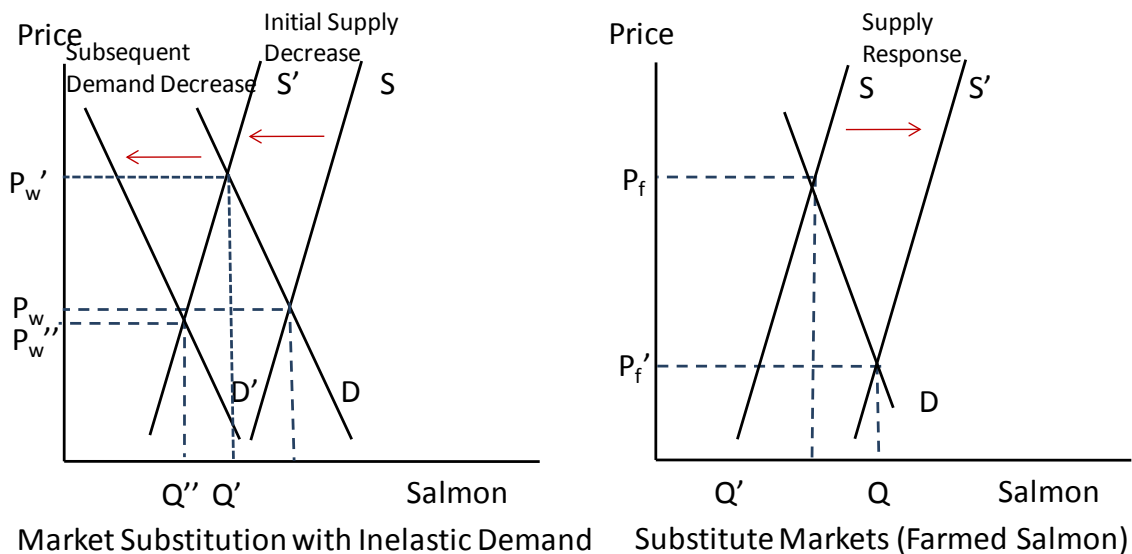


Figure 51. Domestic wild and international farmed salmon markets 1986–mid 2000s.

With consumer preferences recently shifting toward wild over farmed salmon, the demand for wild salmon has increased and become more inelastic (steeper, indicating less sensitivity to changes in market process). With depleted domestic wild stocks, supply will also decrease (shifting the supply curve inward and making it steeper). As pictured in Figure 52, this has caused domestic wild salmon prices to increase in recent years (again, recall Figure 40) and increases future supply side pressures as the wild salmon fisheries have become increasingly profitable.

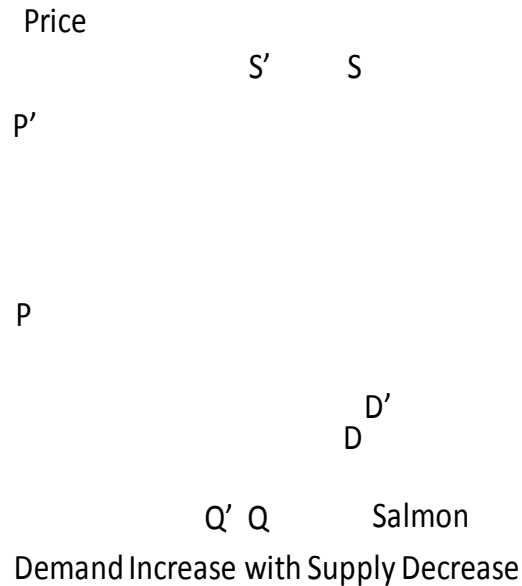


Figure 52. Increasing demand for domestic wild salmon

Given the closure and restrictions in wild catch underway since 2008, the balance of trade deficit will more than likely continue to grow, with imports increasing as U.S. salmon demand increases and U.S. supply decreases for both internal and export markets. Prices for other sources of salmon products have increased, corresponding to growing demand. The scale of global farmed salmon operations will in time reach environmental threshold limits. With limits being reached in the scale of farmed fishing, pressures on domestic wild salmon will only increase further.

Along the West Coast, salmon suppliers at one time were regionally located proximate to concentrations of fishing vessel ports. These locations supported vessels and minimized transportation and transfer costs. With less wild salmon catch available for West Coast regional markets, the wild and fresh preference must be satisfied by product from more distant sources. The delivery costs associated with supply derived from imported wild salmon resources, whether distant or neighboring the United States, further increases domestic wild salmon consumer prices. Associated vessel and transportation operating cost increases will translate into higher prices for consumers. This again will increase pressure for exploiting (further depleting) domestic wild salmon stocks.

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## **VI. FUTURE OUTLOOK RECOMMENDATIONS**

Salmon research and stock management experience over the last 160 years has provided a great deal of information about the natural history and adaptive variation of the salmon species. Foremost in negative impact, dams were built for electricity, flood control and agriculture. Land use practices and development further degraded spawning and rearing habitat. Offsets included hatchery production to supplement diminished runs or produce salmon for the retail market; these offsets became the rationale to allow “catch-up” ephemeral harvests as the fisheries appeared to rebound to historic levels. While this information may have slowed the fishery’s decline, substantial action was not taken to stem the tide of a declining fishery.

Chinook, high in the food web and largest in size were considered more valuable making them preferentially targeted for harvest. Like many capture fisheries, in both developed and undeveloped countries, the resultant declining production and loss of West Coast Chinook was caused by combination of excessive fishing, akin to resource mineral extraction, and extensive riparian and coastal habitat degradation. The declining trend and eventual closure of West Coast Chinook fisheries occurred during a period of global salmon market expansion.

The Johannesburg agreement, in 2002, addressed bringing stocks to MSY by 2015, to ensure greater long-term security for fishery stocks. In 2007, the United Nations Food and Agriculture Organization calculated that 75% of commercial fisheries globally are exploited either up to or beyond their sustainable limits (FAO, 2007). It is apparent that the additional declines in the stock since Johannesburg agreement signal that stocks are moving away from MSY, questioning their long-term survival, than toward the 2015 MSY goal.

The long-term fisheries forecast is that commercial fisheries around the globe have leveled or are in decline, and that aquaculture will be vital to food security and will continue to be the main source of fish (Gilbert, 2002). As aquaculture grows to account for a

larger percentage of total fish supply and production, wild stocks that stabilize will have potential for niche market opportunities, as a special product in limited supply, will also grow for higher quality wild salmon.

Figure 53 shows the forecast on global growth 2005–2030 and growing concerns regarding consumer health and food sources. Global salmon farming, although necessary and developed for global food supply, creates its own consequences when conducted on a large scale. International farmed salmon production does not always incorporate sustainable or environmentally sound practices. The pervasive rationale being, as long as per-capita consumption, driven by market incentives, can be maintained, by replacing natural inputs and functions with partially man-made processes, the environment may largely be ignored and left to deteriorate. Expanding aquaculture operations with innovations and market substitutions, with finite resources, inevitably will result in more complex, costlier, and less effective measures.

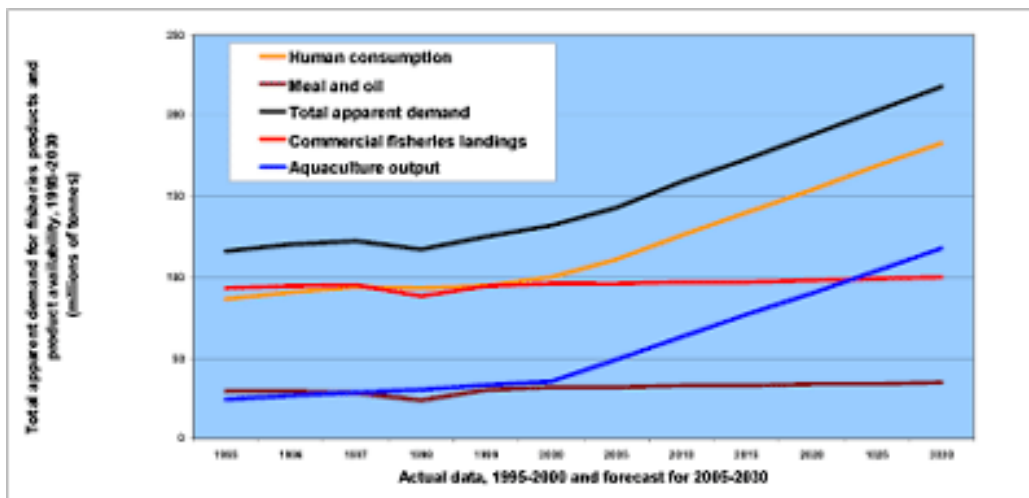


Figure 53. Apparent supply and demand for fisheries—Forecasts for 2005–2030 (From: FAO, 2005).

Farmed growth comes with limiting challenges in the form of disease control, environmental degradation by pollution and impact on wild stocks, changes in regulatory policies, fish feed availability for carnivorous salmon, and changes in consumer sentiment. Viruses, bacteria, and sea lice infestation, pesticides, antibiotics, growth

hormones and genetic modifications linked to the density of fish farmed in offshore areas will serve as controls. Costs will also rise with new technologies and policies developed to address escapement, pollution, and contamination. Development and supply will also be curbed by regional and environmental concerns instituted by sovereign government management. The United States is already limited by regulation in pursuing salmon aquaculture to preserve integrity and improve production of the remaining natural stocks. These factors will limit or prevent additional aquaculture, where wild stocks and environment are already in decline.

Industry consolidation has occurred in both salmon aquaculture and commercial wild salmon. Modern fishing pressures the relationship of economic costs and benefits when harvests are declining and farming development decisions seek to attain profits and net revenues. Limiting wild fishery supply are seasonality, fishing conditions and market demand. Decreased West Coast stock production has reduced the quantity of wild Chinook available to market, as suppliers have not been able to increase landings. As Alaskan and British Columbian wild stocks also experienced subsequent decline, the aggregate decrease in the number of active commercial fishers and unstable sustainable management practices have significantly curbed the ability of the wild salmon fishery to meet demand by increasing production as farmed salmon supply has grown.

As salmon aquaculture has grown in abundance and availability, providing a year round reliable substitute, it has solidified its global market presence and decreased consumer salmon prices. With this competition, additional declines in West Coast wild stock harvests affected the ability of wild supply to compete. Aquaculture, thereby, served as a key development to meet increasing demand for salmon. Aquaculture growth continues to pressure the wild fishery price, harvest, and supply chain. Wild harvest lost market share as aquaculture grew. Global consumer demand for imported foreign salmon and farmed fish production then surpassed wild U.S. exports.

Figure 54 shows the challenging marketing elements for wild salmon. Inventory is the primary challenge, where wild salmon cannot compete directly with farmed salmon production. Fresh products, in most cases, will receive a price premium compared to their artificially colored farmed or frozen salmon substitutes. For wild Chinook, flesh is

usually a red to radiant orange, some are white. Consumer quality preference for red meat commands a higher price over less vibrant farmed salmon (Knapp et al., 2007). In 2004, Alaska fishing organizations and seafood processing companies initiated policies to revitalize the salmon industry, through both national and international education and awareness programs, promoting Alaska's premium wild salmon. Copper River King Salmon, as example, sold for as much as \$36.99 per pound retail.

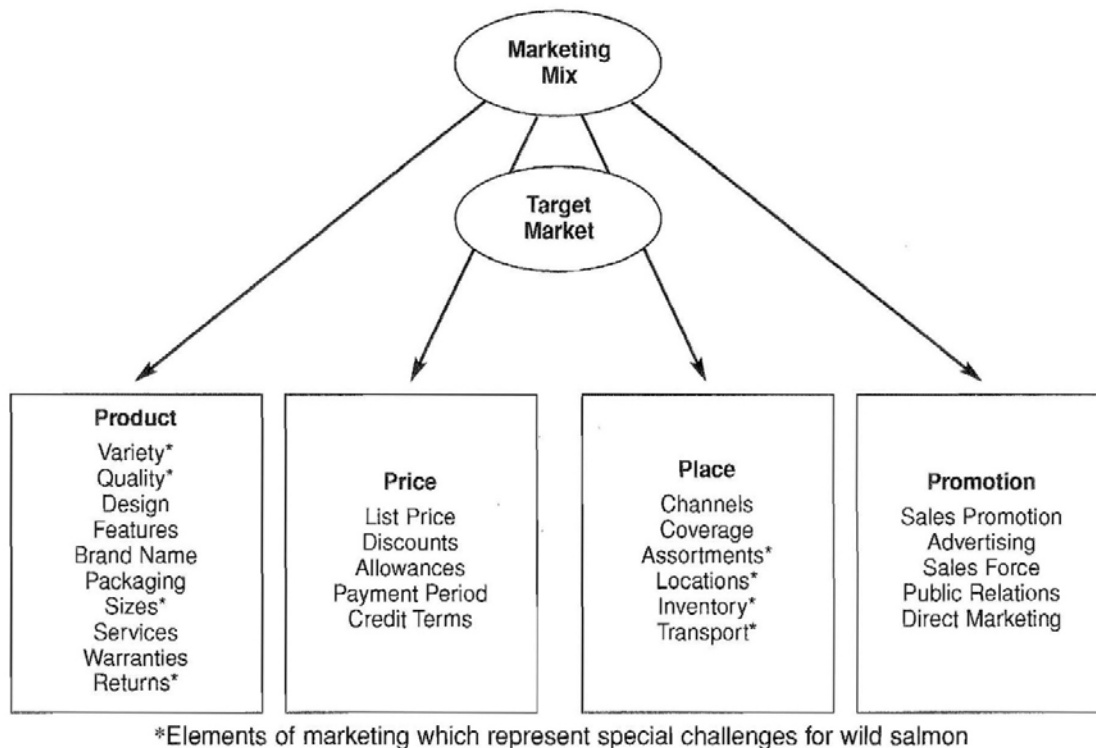


Figure 54. Target marketing variables (From: Knapp et al., 2007).

Farmed salmon market share has grown over the last 25 years and became the leader in supply and in driving price. The relaxed demand for wild quality led to lower prices with a lesser quality salmon. This resultant competition and premium for wild salmon stock increased harvest pressure and competition for market share. The timing of the increased unsustainable harvest that followed, aided in the fishery's further collapse, including reductions in fishers and vessels. Fishing practices and habitat pressure on the Chinook brought the population to historically low productivity, unable to sustain a West Coast Chinook supply. Marketing the limited wild salmon supply has led to a two-fold

wild salmon price increase in three years. A result of limited supply and market premium is increasing pressure on local wild fisheries. Wild harvest will continue as a premium market with consumers willing to pay higher prices than for farmed salmon.

Conserving and restoring the iconic West Coast King or Chinook salmon species is a key to exploit this brand name product for market presence. Promotion and market strength of wild salmon supply will also raise questions about the variety and quality of farmed salmon. A move toward quality would increase demand for the wild product. Consumption elasticity is important in consumer decision patterns (Knapp et al., 2007); and quality salmon products appear to have inelastic demand. With declines in perceived farmed salmon quality, wild salmon suppliers have an offset to competition through differentiating wild stocks as a superior product to mass-produced farm-raised salmon. Maintenance of a consumer niche market allows wild natural salmon to be revitalized and sold at higher or premium prices to farmed stock. A limited yet sustainable wild West Coast Chinook harvest offers differentiation among farmed product and with marketing creates public awareness of stewardship concerns. A successful wild fishery will translate into a premium return for the product supplied. The rebound of sustainable levels of West Coast stocks, paired with brand strategy, should translate into premium retail.

The Marine Stewardship Council (MSC), established in 1997 by Unilever, the world's largest seafood buyer, has developed environmental standards and branding for promoting sustainable and well-managed fisheries. Europe is under pressure from environmental non-government organizations (NGOs) to have a sustainable policy that is independently verified. Branding and certification by the Marine Stewardship Council of the Alaskan Chinook salmon fishery will establish a market edge leading to steady or increasing prices to the benefit of the wild Chinook supply chain. The Alaska Seafood Marketing Institute (ASMI) asserts that the Alaskan Constitution and state law define any fish caught legally as sustainable. At a minimum, restoring the specific West Coast Chinook populations to a sustainable fishery that attains and sustains MSC certification would enable niche wild product marketing.

Reversing the path toward extinction of a species to one of recovery is a challenging undertaking, requiring a change in practice and policy. This change can only

be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift federal, state agencies and societal attitudes, practices and understanding. State and federal fishery management, in Western states, however, has not protected stock longevity and sustainability and has not sufficiently minimized or mitigated environmental harm. West Coast salmon requires restoration and management practices adjusted to competing priorities as a means toward re-establishing market level sustainability.

For West Coast Chinook production to regain market share, riparian water conservation and fishing policy measures must first be stabilized to protect and allow wild salmon populations to recover. Without preserving healthy drainage runs and restoring endangered runs on the three big main stem, salmon-producing rivers, the Sacramento (California), Klamath (Oregon), and Columbia-Snake (Oregon and Washington), market supply will be limited by salmon originating in those rivers. Protecting core areas critical to stock persistence and restoration of a broader matrix of productive habitats is increasingly necessary to achieve a productively stable and sustainable fishery. Achieving and maintaining both regional and state sustainability will help restore West Coast market presence and increase product supply. Policy action to bring healthy sustainable stocks to market will be rewarded with initiatives like the Marine Stewardship Council certification, improvement in regional ecology, provided stocks are allowed to develop a consistent abundance level.

If the West Coast Chinook are faced with a protracted return or are not restored and Alaskan and British Columbia stocks remain pressured, the market will strengthen those remaining imported wild Chinook or other wild salmon species, which will benefit in price from the natural “wild” fishery association. Without dramatically addressing the balance of these issues, the U.S. West Coast wild Chinook range and supply will continue to be historically limited. With forecasted growing seafood consumption and a market preference for wild stock, when available, supply will ultimately be derived from multiple sources. With West Coast stocks limited, fresh wild Chinook sources will be distant to the West Coast.

With over a century of research recognizing that Chinook stocks have varied and declined, it is reasonable to propose that multiple missed opportunities resulted in collapse of the wild Chinook stock. Loss of production was inevitable, as West Coast Managers have demonstrated a bias against sustainable development (Clark, 1991). West Coast and national management repeatedly failed to aggressively plan for the future sustainability and balance competing elements. Risk and loss were not taken as seriously as the immediate potential payoff (Gieger & Gharret, 1997). Management failed to factor in declines in natural production and the impact of hatchery production so as to curb wild harvest to and allow wild stocks to recover before stock yield reached economic collapse.

The relationship between man's population and the salmon resource has existed for centuries. For more than a century, however, Western U.S. Chinook ventures and management have not insured the long-term health of the resource. It is critical that management structures and decisions are broadened to consistently balance sound biological, social, economic, and other management objectives to restore and maintain sustainable fisheries. A profitable fishery is of direct interest to fishermen, to sustain their livelihoods. Restoring the opportunity to harvest a long-term sustainable market depends critically on cohesive decisions that are effective and systematic resource and ecosystem management and regulatory measures. Linking biology and economics through integrated population models can provide metrics for science-based policy and management. Saving or restoring sustainability within the Chinook fishery tests society's willingness to address problems associated with continued population growth and resource consumption; otherwise, the U.S. West Coast wild Chinook supply will continue to be limited.

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